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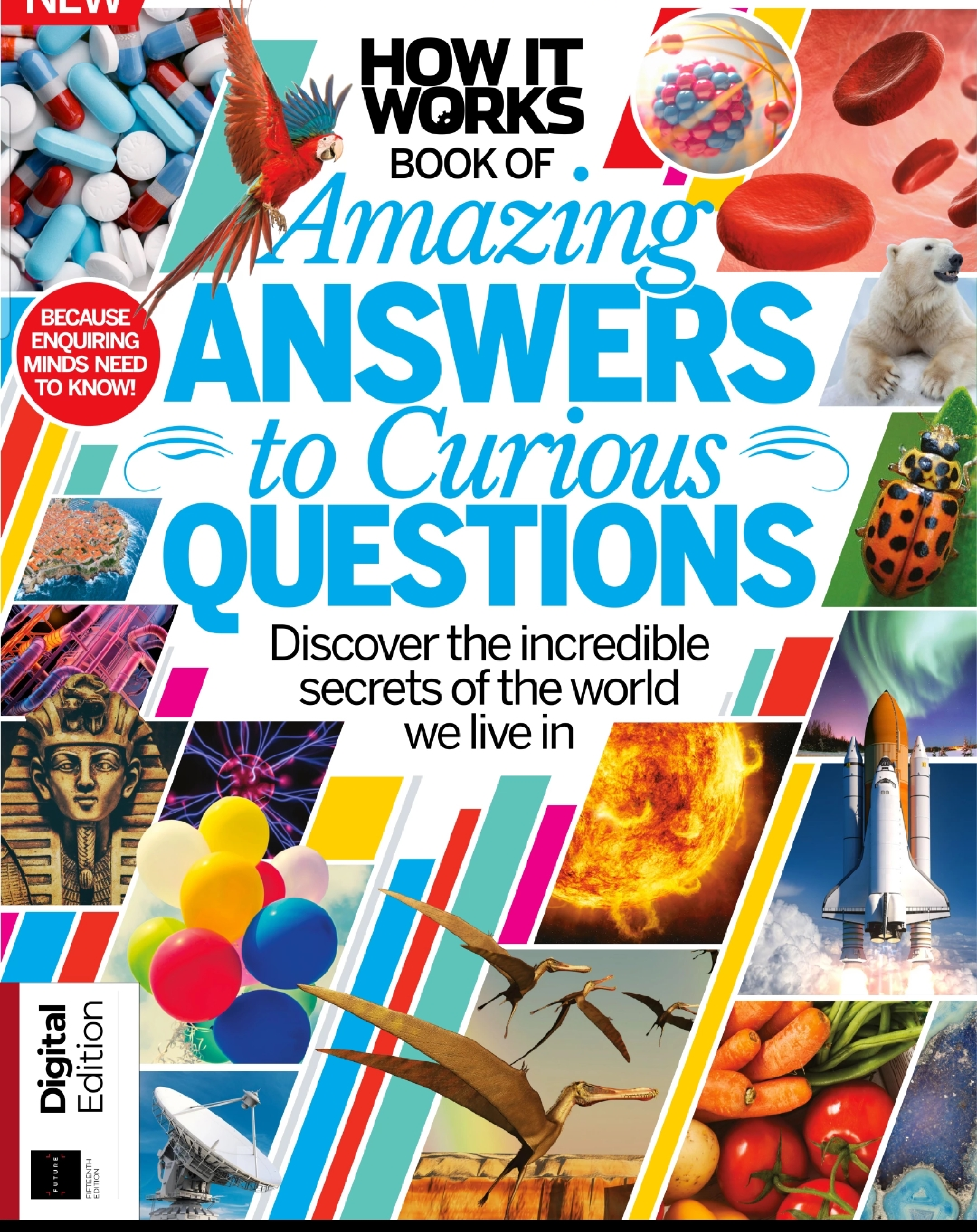

HOW IT WORKS
BOOK OF
Amazing ANSWERS *to Curious* QUESTIONS

BECAUSE ENQUIRING MINDS NEED TO KNOW!

Discover the incredible secrets of the world we live in

Digital Edition

FUTURE
FIFTEENTH EDITION

Welcome to Amazing ANSWERS to Curious QUESTIONS

If you're curious about the world we live in and everything in it, you've come to the right place! In How It Works Book of Amazing Answers to Curious Questions, discover the elusive explanations behind life's most intriguing conundrums. How do landslides happen? Head to the Environment section to find out. Have you ever wondered what's harder: brain surgery or rocket science? Flick to the Science section. Are you interested in finding out what the technology of 2050 will be like? That's in the Technology section. With sections dedicated to six themes, including Space, Transport and History, you are sure to satisfy your hunger for knowledge within these pages. So if you've ever pondered how Earth got its core or how fossils are formed, join the club and continue reading!

FUTURE

HOW IT WORKS BOOK OF *Amazing* ANSWERS *to Curious* QUESTIONS

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Contents

AMAZING ANSWERS TO CURIOUS QUESTIONS

Environment

12 How can we save the world?
18 What are crystal giants?
20 Why do rivers meander?
20 What is a soybean plant?
21 Do snakes need two tongue tips?
21 Why do whales become beached?
22 What are Earth's land habitats?
24 How do we predict the weather?
26 What causes a landslide?
28 How are rocks recycled?
29 What causes wind patterns?
30 Bitesize Q&A

> "No other organism in Earth's history has altered the environment so much, so quickly"

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Technology

36 What will life be like in 2050?
44 How do keys open doors?
45 How do food blenders work?
46 How do we turn waste into energy?
48 How are digital images captured?
49 How do wristwatches tick?
50 How do industrial robots work?
52 How does new tech fight fires?
54 Bitesize Q&A

Space

60 What future could we have in space?
66 How fast are you moving?
66 How are spacecrafts docked?
67 What are white holes?
68 What animals have been to space?
69 How far can we see?
70 How do frozen worlds form?
70 How do we search for super-Earths?
71 What near misses will Earth have?
72 What is the Sun made up of?
74 Bitesize Q&A

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Science

80 What's harder: brain surgery or rocket science?
86 How do our hearts beat?
88 What is the pH scale?

88 What if we ran out of rare Earth metals?
89 What is the blood-brain barrier?
90 What makes hair curl?
90 Why do our ears pop?
91 What's in a name?
92 What if the magnetic field flipped?
92 How do dogs drink?
93 What are enclosed eco-systems?
94 What if gravity was twice as strong?
94 What are the colours of blood?
95 Is there such a thing as perfect posture?
96 How do hydraulics work?
97 How do nuclear power plants work?
98 Bitesize Q&A

History

104 What are the prehistoric monsters?
110 What did it take to become a knight?
111 What jobs were there in the Middle Ages?
112 What was surgery like in the Victorian era?
114 What is the significance of Fabergé eggs?
115 How was the Thames tunnel built?
115 What are the world's tallest statues?
116 What was the biggest sloth?
117 How were typewriters built?
118 How do fossils form?
120 Bitesize Q&A

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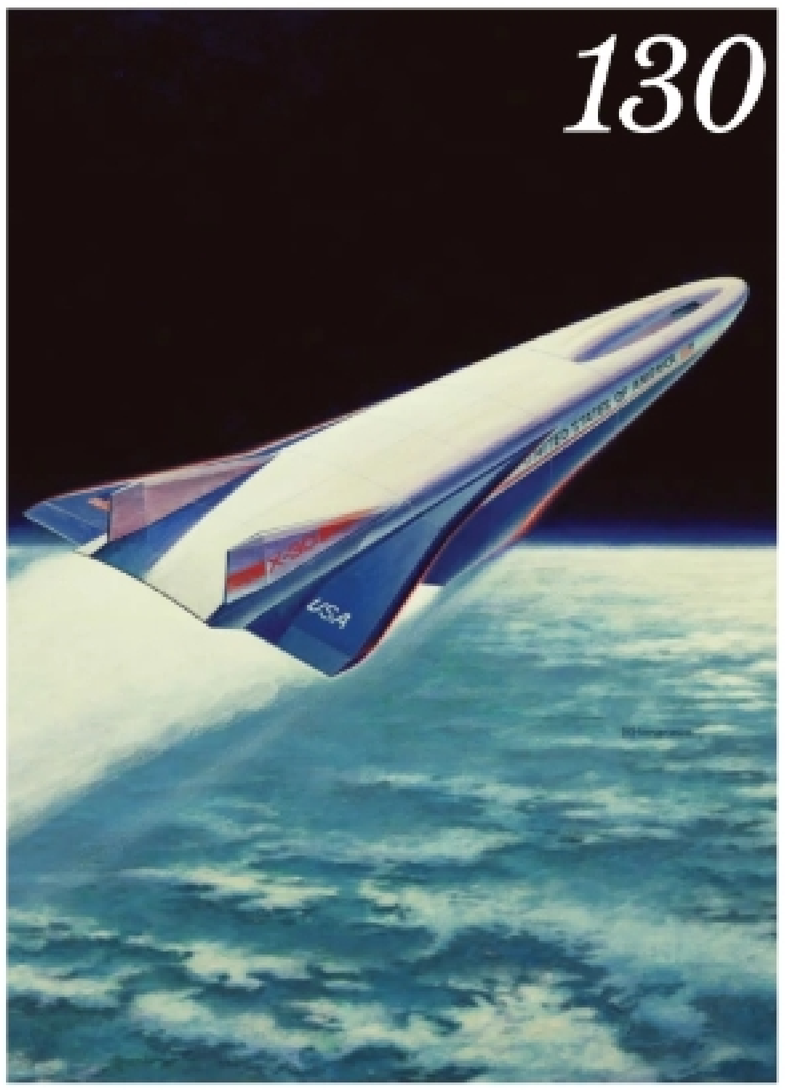
Transport

126 How do solar-powered planes work?
130 Will rockets replace planes?
134 How do gliders stay airborne?
135 What are shipping lanes?
135 How do cat's eyes work?
136 Why do leaves on the line affect trains?
136 How do wingsuits work?
137 How does the Sailrocket 2 work?
138 How do trams work?
138 How do you balance on a unicycle?
139 What makes up a road?
139 How do trains change tracks?
140 Bitesize Q&A

138


130

126

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Environment

12 How can we save the world?
18 What are crystal giants?
20 Why do rivers meander?
20 What is a soybean plant?
21 Do snakes need two tongue tips?
21 Why do whales become beached?
22 What are Earth's land habitats?
24 How do we predict the weather?
26 What causes a landslide?
28 How are rocks recycled?
29 What causes wind patterns?
30 Bitesize Q&A

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How can we save the world?

Discover the incredible science and tech that will protect our planet

8 million tons
The amount of plastic waste that enters the ocean each year

1 trillion
The number of plastic bags used each year worldwide

100 kilograms
The average amount of food thrown away every year per person in the UK – over half of which is perfectly edible!

100,000
The number of marine mammal deaths caused by plastic debris each year

90%
Proportion of the world's seabirds estimated to have ingested plastic, including bags and bottle tops

75,000
The number of trees that would be saved by recycling just a single run of the Sunday New York Times

15-30%
The proportion of childhood asthma cases that are thought to be triggered by air pollution

© Corbis

Can we stop global warming?

While governments squabble over carbon emissions, innovative technology could help to slow temperature rises

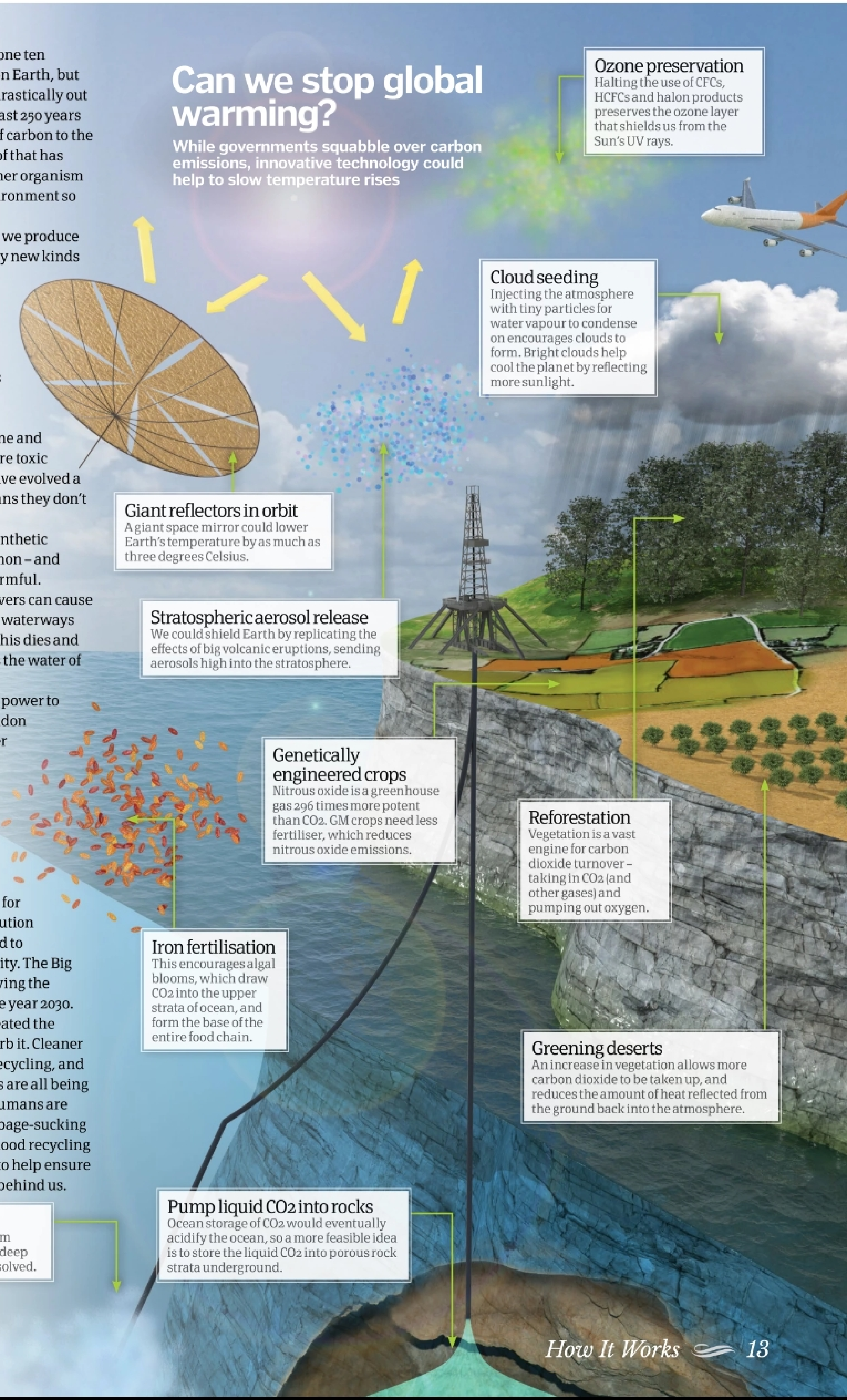
Humans only make up about one ten thousandth of the biomass on Earth, but our impact on the planet is drastically out of proportion to our numbers. In the last 250 years we have added over 400 billion tons of carbon to the atmosphere and approximately half of that has happened since the mid-1980s. No other organism in Earth's history has altered the environment so much so quickly.

It's not just the amount of pollution we produce either; humans have invented entirely new kinds of pollution too. Polythene, chlorofluorocarbons, organophosphates and synthetic hormones didn't exist in the environment until humans created them. Other toxins, like heavy metals and radioactive isotopes, were only there in trace amounts until the industrial age found new ways to refine and concentrate them. These pollutants are toxic because they are too new for life to have evolved a way of dealing with them, which means they don't get broken down either.

A 2007 study found more than 24 synthetic chemicals and pesticides in wild salmon – and non-toxic pollutants can be just as harmful. Fertilisers that run off the land into rivers can cause such a sudden explosion of algae that waterways are blocked with green slime. When this dies and decays, the surge in bacteria depletes the water of oxygen and kills off the fish.

But pollution is entirely within our power to control. In 1952, the Great Smog of London killed an estimated 12,000 people over four days, but four years later the Clean Air Act was passed and air quality steadily improved. The countries that were once the biggest polluters have also been the first to introduce emissions standards. Just 50 years ago, New York City was plagued by a dense smog responsible for around 24 deaths per day, but air pollution legislation and incentives have helped to drastically improve the city's air quality. The Big Apple is even working towards achieving the cleanest air of any major US city by the year 2030.

The technological progress that created the pollution can also be harnessed to curb it. Cleaner fuels, more efficient engines, better recycling, and environmental clean-up technologies are all being developed to slow the rate at which humans are poisoning the planet. From huge, garbage-sucking machines in the ocean to neighbourhood recycling schemes, there is a way for everyone to help ensure that Earth's most polluted century is behind us.



Ozone preservation
Halting the use of CFCs, HCFCs and halon products preserves the ozone layer that shields us from the Sun's UV rays.

Cloud seeding
Injecting the atmosphere with tiny particles for water vapour to condense on encourages clouds to form. Bright clouds help cool the planet by reflecting more sunlight.

Giant reflectors in orbit
A giant space mirror could lower Earth's temperature by as much as three degrees Celsius.

Stratospheric aerosol release
We could shield Earth by replicating the effects of big volcanic eruptions, sending aerosols high into the stratosphere.

Genetically engineered crops
Nitrous oxide is a greenhouse gas 296 times more potent than CO_2. GM crops need less fertiliser, which reduces nitrous oxide emissions.

Reforestation
Vegetation is a vast engine for carbon dioxide turnover – taking in CO_2 (and other gases) and pumping out oxygen.

Iron fertilisation
This encourages algal blooms, which draw CO_2 into the upper strata of ocean, and form the base of the entire food chain.

Greening deserts
An increase in vegetation allows more carbon dioxide to be taken up, and reduces the amount of heat reflected from the ground back into the atmosphere.

Pump liquid CO_2 into deep sea
CO_2 could be liquefied under pressure from industrial exhaust gas, and pumped into deep ocean waters, where it would remain dissolved.

Pump liquid CO_2 into rocks
Ocean storage of CO_2 would eventually acidify the ocean, so a more feasible idea is to store the liquid CO_2 into porous rock strata underground.

Ground pollution

The toxic chemicals lurking beneath the surface of our poisoned planet

Land pollution isn't just about the space that is taken up by landfill. A city the size of New York could fit all of its rubbish for the next thousand years in a landfill 56 kilometres long by 56 kilometres wide. That sounds like a lot, but that's the waste of just 2.5 per cent of Americans buried in just 0.03 per cent of the country's land area. And that land isn't gone forever – eventually a landfill site will just become a grassy hill.

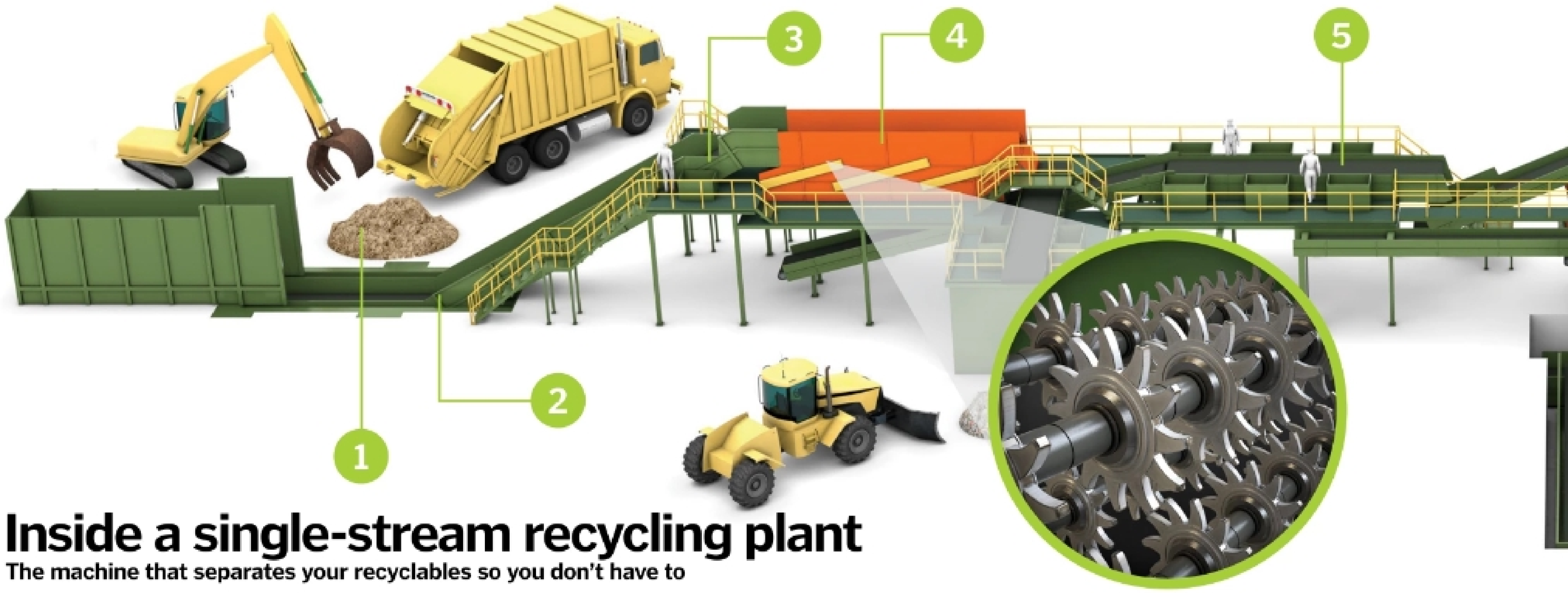
The real source of land pollution is all of the other things that don't end up in landfill. Copper and aluminium mining generate huge piles of powdered rock, called 'tailings', left behind after the metal has been extracted. These tailings are high in toxic heavy metals, such as mercury and cadmium, and aluminium mining alone generates more than 77 million tons of tailings worldwide every single year.

Modern farming also requires more than just sunshine and rain. In the UK, farmers add an average of 100 kilograms of nitrogen fertiliser to every hectare of arable land and grassland each year. Whatever the crops don't absorb gets washed into the groundwater and ends up in our rivers, going from land to water pollution.

The low-tech solutions to land pollution are the three Rs: reduce, reuse, recycle, and these are in decreasing order of effectiveness. Reducing the amount of cardboard or cabbage you need to buy in the first place has a much bigger impact than simply recycling all the leftovers, because it also saves the energy that would have been required to process and transport them to you, and then collect and recycle them again afterwards.

But there are high-tech pollution solutions as well. Bioremediation uses selected strains of naturally occurring organisms to break down contaminants in the soil. Wood fungi for example, have been shown to be able to break down the toxins in oil spills and also certain chlorine pesticides.

Heavy metals like cadmium and lead can't be broken down, but certain plants will take them up through their roots and store them in their leaves or stems. This technique, which is known as phytoremediation, uses plants to soak pollutants from the ground so that they can be removed more easily. Chinese brake fern can even filter out arsenic in this way.



Inside a single-stream recycling plant

The machine that separates your recyclables so you don't have to

Waste from construction sites can be recycled at specialised plants

1 Tipping floor

A steady stream of recycling collection vehicles arrives at the facility, dumping their cargo of mixed recyclables out onto the tipping floor. Drivers look out for any oversized objects like car engines that would cause damage to the plant machines.

2 Loading

Powerful loaders shunt piles of assorted recyclables into a large hopper, where they are tumbled over a rotating drum to loosen compacted materials. They then flow onto a giant conveyer belt, which whisks the jumble into the main facility.

3 Manual pre-sort

Teams of human sorters pick out non-recyclable items from the fast-moving stream, including crisp packets, plastic bags, shoes and nappies, as well as large items like scrap metal that might jam the machines.

4 Star screen sorting

A series of vibrating, rotating shafts, fitted with offset star-shaped discs, lift large and light materials like cardboard upwards; smaller items like paper, bottles and cans fall through and continue on the conveyer belt.

5 Medicinal wonder

For a second time, teams of human sorters stand at intervals along the conveyer belt and look out for any smaller contaminants that might have snuck into the mix, such as personal electronics, trinkets, wallets and pieces of food.

6 Star screens round two

A trio of finer-grained star screens sift out different grades of paper, which are directed towards dedicated storage units. Glass, metals and plastics fall through the screens again and continue on the conveyer belt.

What your rubbish could become

One person's trash is another person's eco-friendly treasure

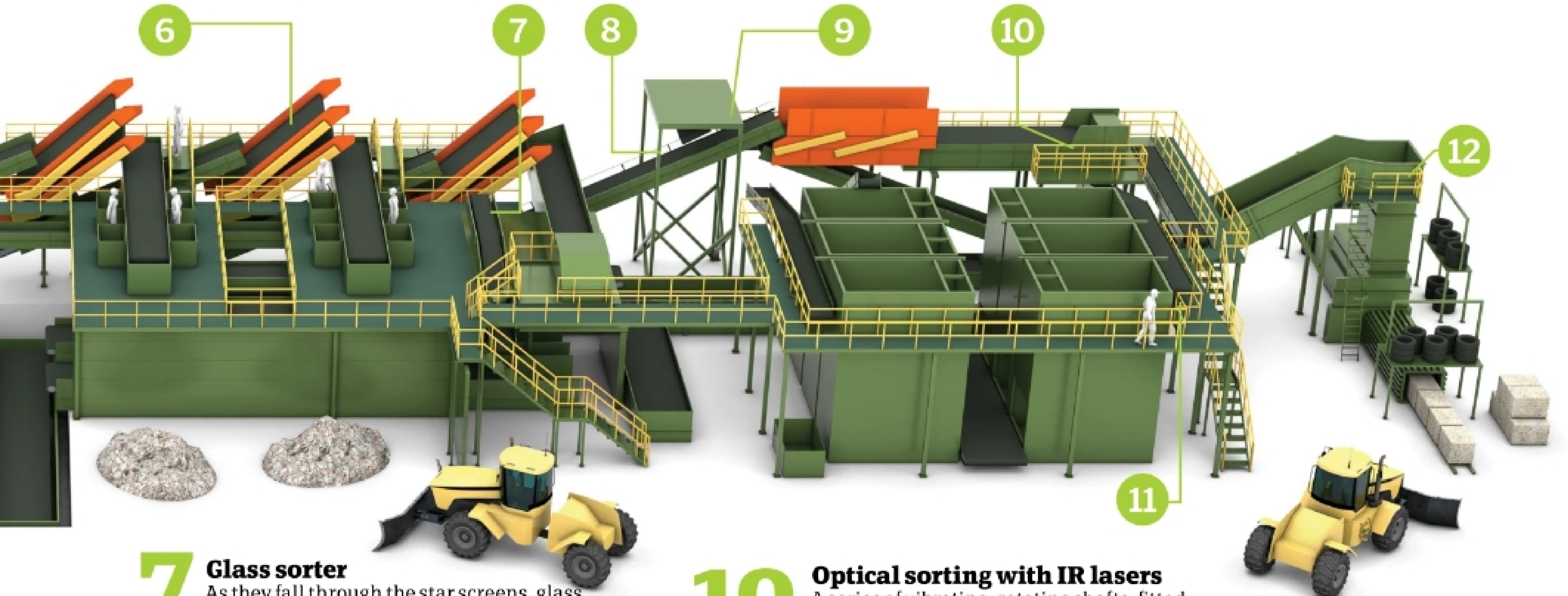
From: Plastic drink bottles (PET)
To: Fleece jacket

From: Plastic milk jugs (HDPE)
To: Children's toys

From: Tyres
To: Sports and playground surfaces

From: Glass bottles and jars
To: New bottles and jars

From: Cardboard and paper
To: Newspapers, cards



7 Glass sorter

As they fall through the star screens, glass containers get crushed by the rotating stars. The fragments fall into bins below the screens, and are transported off site to be sorted by colour and ground into coarse sand.

8 Steel magnet

The remaining materials pass under a powerful rotating belt magnet, which lifts out tin and steel cans and drops them into a storage bunker. This usually only removes around four per cent of the recyclables passing through the plant.

9 Eddy current separator

Since aluminium isn't magnetic, it is picked out using a strong reverse magnet called an eddy current separator. This uses spinning magnets to induce a current in the cans, which makes them fly off the belt and into a bunker.

10 Optical sorting with IR lasers

A series of vibrating, rotating shafts, fitted with offset star-shaped discs, lift large and light materials like cardboard upwards; smaller items like paper, bottles and cans fall through and continue on the conveyer belt.

11 Manual sorting

The remaining plastics are carefully sorted by teams of workers. They also perform a last check, picking out and redirecting any recyclable items that have been missed by the mechanical processes and remain on the line.

12 Baler

One at a time, the bunkers are opened, pouring out plastic, cans, metals or paper. Baling machines compress these into cubic bales ready to be taken to reprocessing plants for recycling. Any leftover materials at this point go to a landfill site.

© Peter Craven, Illustration by Graham Murdoch

Air pollution

With the potential to cross international boundaries, air pollution is a truly global problem

Air pollution is the introduction of gases and particles into the atmosphere that have harmful effects on living creatures and the built environment. According to the World Health Organisation, 7 million premature deaths are caused every year by people inhaling polluted air – that's one in eight deaths worldwide. Once released into the atmosphere, pollutants are impossible to contain and – depending on prevailing weather patterns – have the potential to affect people who are hundreds or even thousands of kilometres from the source.

Over the last half century, the nature of the problem has altered. In the developed world, smog-causing emissions of noxious smoke, sulphur dioxide and particulates associated with incomplete fuel combustion have been curbed by technologies like flue-gas desulphurisation systems, soot scrubbers and catalytic converters. Gases that deplete the stratospheric ozone layer most aggressively have been outlawed and replaced by safer compounds, and today it's the threat of global warming that looms largest.

There is growing evidence, however, that respiratory problems like asthma might actually be caused by air pollution, not just triggered by it. Some researchers have even made tentative links between neighbourhood air quality and rates of childhood autism.

As with other forms of pollution, the best way to protect the environment is to avoid releasing these toxic elements in the first place. Conserving electricity, driving mindfully, and choosing to walk, cycle or take public transport are easy choices we can all make in order to breathe just a little easier.

Beijing issued its first ever 'red alerts' for hazardous smog in December 2015

Atmospheric pollutants

The major contributors to environmental damage

Carbon monoxide (CO)

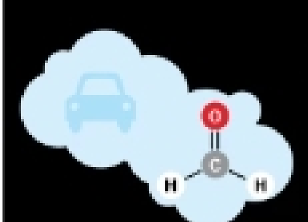
This gas is produced when fossil fuels burn incompletely, with road vehicles being the predominant source.

Ozone (O_3)

This is formed when other pollutants react in the presence of heat and sunlight. It triggers lung irritation and asthma attacks.

Nitrogen oxides (NO_x)

These form during fossil fuel combustion and contribute to global warming, smog and ground level ozone formation.



Volatile Organic Compounds (VOCs)

In the presence of pollutants, these carbon-based chemicals contribute to the formation of ground level ozone and smog.

Sulphur dioxide (SO_2)

This is produced during incomplete combustion in coal-fired power stations and fireplaces. It contributes to smog and acid rain.

Particulates

These include airborne dust, dirt, soot and smoke. They can cause respiratory problems and environmental damage, such as acidification of lakes.

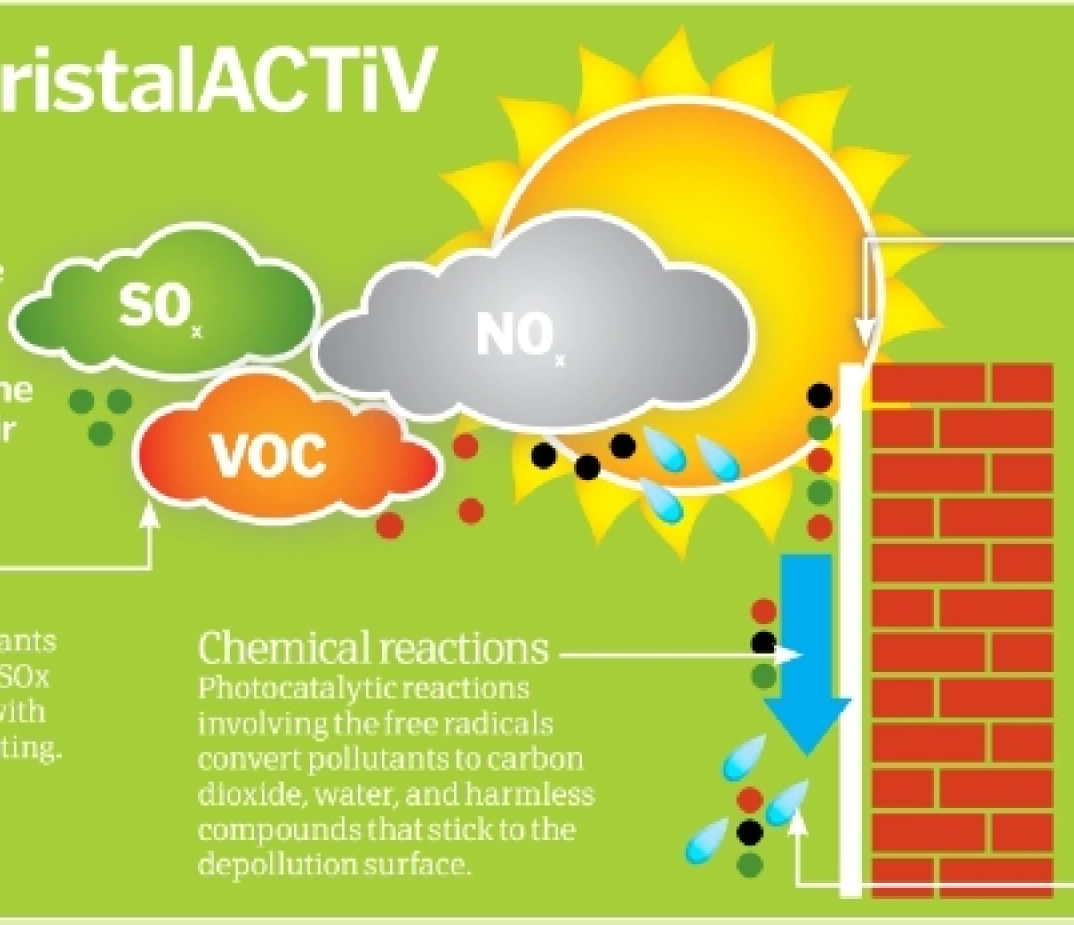
Photocatalysis

In some cases, airborne pollutants convert to harmless materials when they react chemically with other atmospheric gases. These reactions happen naturally in the presence of light, but on a slow timescale. In photocatalysis, the rate of these everyday reactions is boosted using a specific catalyst.

Innovative chemical company Cristal has pioneered a pollution-busting coating that can be painted directly onto buildings. Made from ultra-fine photocatalytic titanium dioxide (TiO2), it actively draws pollutants including VOCs, NOx and sulphur dioxides from the surrounding air and converts them into harmless by-products that are easily washed away. Best of all, the catalyst itself is not used up in the reaction, so its performance never dips.

How CristalACTiV works

This clever coating can be painted on structures to help cleanse the surrounding air



Pollutants Photoreactive atmospheric pollutants like VOCs, NOx and SOx come into contact with the depollution coating.

Chemical reactions Photocatalytic reactions involving the free radicals convert pollutants to carbon dioxide, water, and harmless compounds that stick to the depollution surface.

Depollution coating Under the sun's UV light, the titanium dioxide (TiO2) coating forms highly reactive free radical particles, capable of breaking down pollutants.

Self-cleaning surface The soiled surface is washed clean whenever rain falls, or it is hosed down.

© Rex Features

Ocean pollution

From oil and debris to sewage and toxic chemicals – our seas have it all

Oceans cover 71 per cent of our planet's surface and contain an estimated 1.5 million species, but that hasn't stopped humanity treating the sea as a giant, watery rubbish bin.

We're familiar with tragic images of seabirds whose feathers are clogged with viscous black oil. But catastrophic spills from tankers account for just a fraction of oil pollution in the sea; street runoff, vehicle exhausts and industrial waste are all chronic contributors to the problem.

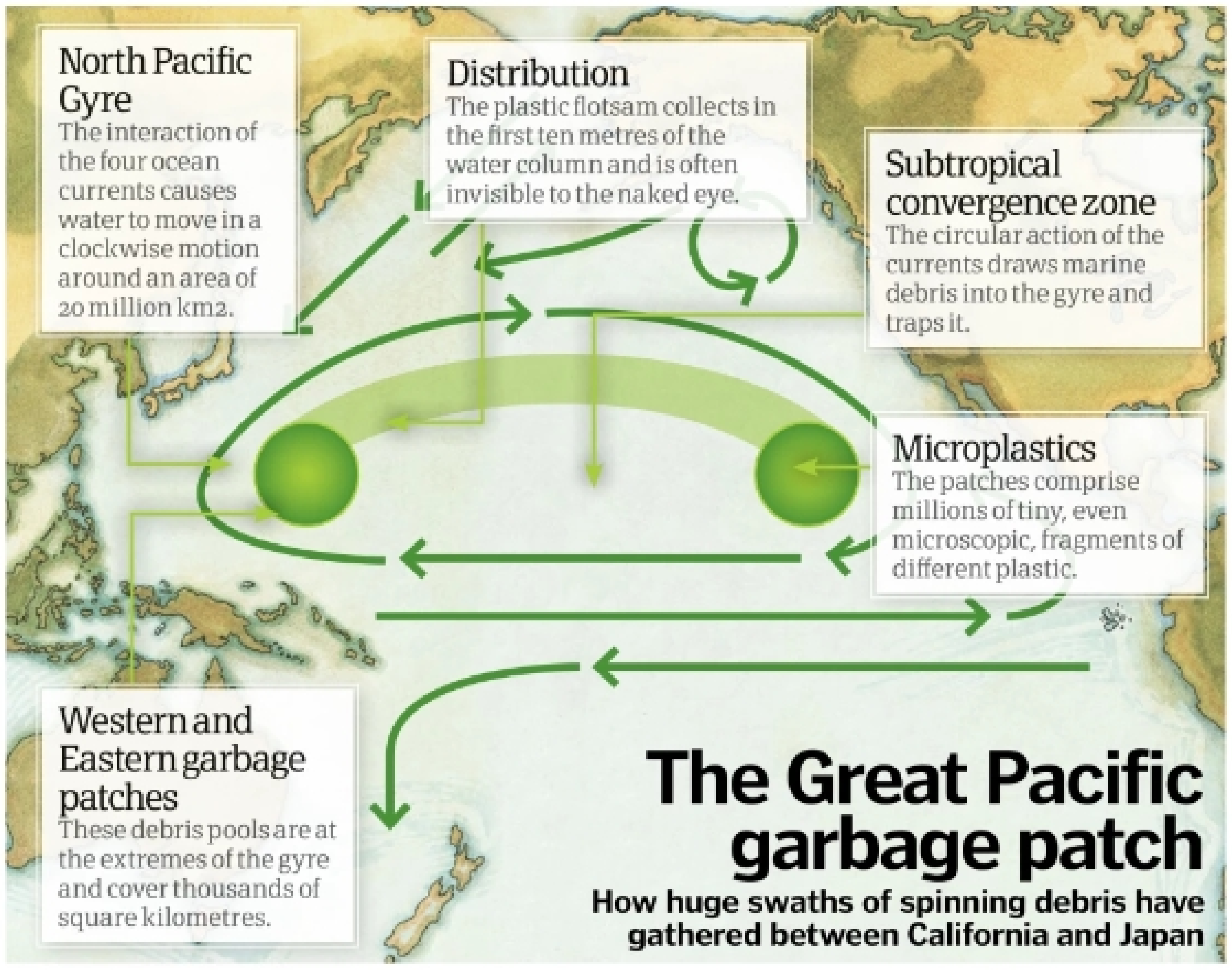
Indeed, almost all marine pollution stems from activities on land. Runoff from farms introduces pesticides and insecticides into the aquatic food chain, as well as an overabundance of nutrients in the form of fertiliser. This causes populations of algae to spike, draining the surrounding waters of oxygen and suffocating other marine life.

Finally, human-made rubbish is ubiquitous throughout the world's oceans, where it is corralled by currents into vast swirling 'garbage patches'. Many items, including fishing gear, glass, metal, paper, cloth and rubber, can take years, decades, or even centuries to decompose in some cases.

The worst offenders – plastics – essentially persist forever, but are broken down under the Sun's UV rays into ever smaller pieces. The eventual soup of 'microplastics' – invisible to the naked eye – poses a threat to wildlife that ingests it, and to the entire food chain due to the leeching of harmful chemicals.

There are no easy solutions, but a burst of new technologies may begin to turn the tide. In just 18 months, 'Mr Trash Wheel', a filtering water wheel with its own Twitter account, has removed over 400 tons of rubbish from Inner Harbor in Baltimore, US. Proposals for open ocean filtration systems include a solar-powered 'vacuum boat' called SeaVax, that its inventors claim will suck up 22,000 tons of garbage each year.

The most common items washed up on beaches include plastic bottles and cutlery, and coffee cup lids. The good news is that means we can help by making simple changes to our lifestyles, like carrying reusable water bottles and utensils.



The Great Pacific garbage patch

How huge swaths of spinning debris have gathered between California and Japan

North Pacific Gyre
The interaction of the four ocean currents causes water to move in a clockwise motion around an area of 20 million km2.

Distribution
The plastic flotsam collects in the first ten metres of the water column and is often invisible to the naked eye.

Subtropical convergence zone
The circular action of the currents draws marine debris into the gyre and traps it.

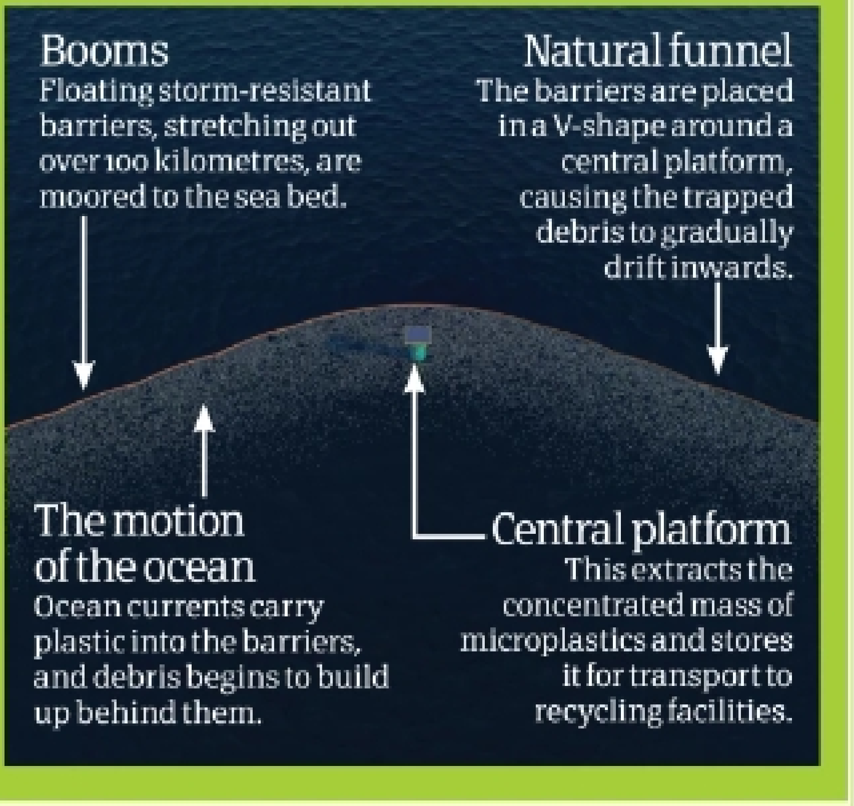
Microplastics
The patches comprise millions of tiny, even microscopic, fragments of different plastic.

Western and Eastern garbage patches
These debris pools are at the extremes of the gyre and cover thousands of square kilometres.

The Ocean Cleanup Array

The brainchild of 21-year-old Dutch inventor Boyan Slat, the Ocean Cleanup Array harnesses ocean currents to sweep floating plastic debris into a gigantic 100-kilometre long collector for recycling. The innovative system comprises a pair of floating barriers, held in a V-shape, that skim tiny pieces of plastic flotsam from the oncoming currents while allowing the sea life to pass safely underneath it.

The crowdfunded project – now at the model testing stage – has the potential to remove over 7 million tons of microplastics from the world's oceans, and its creators claim that a single Ocean Cleanup Array could halve the size of the Great Pacific Garbage Patch in just ten years.



Booms
Floating storm-resistant barriers, stretching out over 100 kilometres, are moored to the sea bed.

Natural funnel
The barriers are placed in a V-shape around a central platform, causing the trapped debris to gradually drift inwards.

The motion of the ocean
Ocean currents carry plastic into the barriers, and debris begins to build up behind them.

Central platform
This extracts the concentrated mass of microplastics and stores it for transport to recycling facilities.

Marine debris timeline

How long does common rubbish persist in the ocean?

Cigarette butt

The most common item found on beach clean-ups, making up 25 per cent of all collected debris. They contain a synthetic fibre that takes years to break down.

Aluminium can

An aluminium oxide coating makes aluminium cans very resistant to dissolving in sea water. Frustratingly, they are one of the simplest items to recycle.

Plastic drink bottle

Plastics degrade into tiny pieces, but they never fully disappear. Americans alone throw away over 35 billion plastic water bottles per year.

Disposable nappy

Nappies are made from multiple layers, including various long-lived plastics like polythene and polyester. They easily outlive the child that wears them.

© Thinkstock, Dreamstime, Erwin Zwart/The Ocean Cleanup

What are crystal giants?

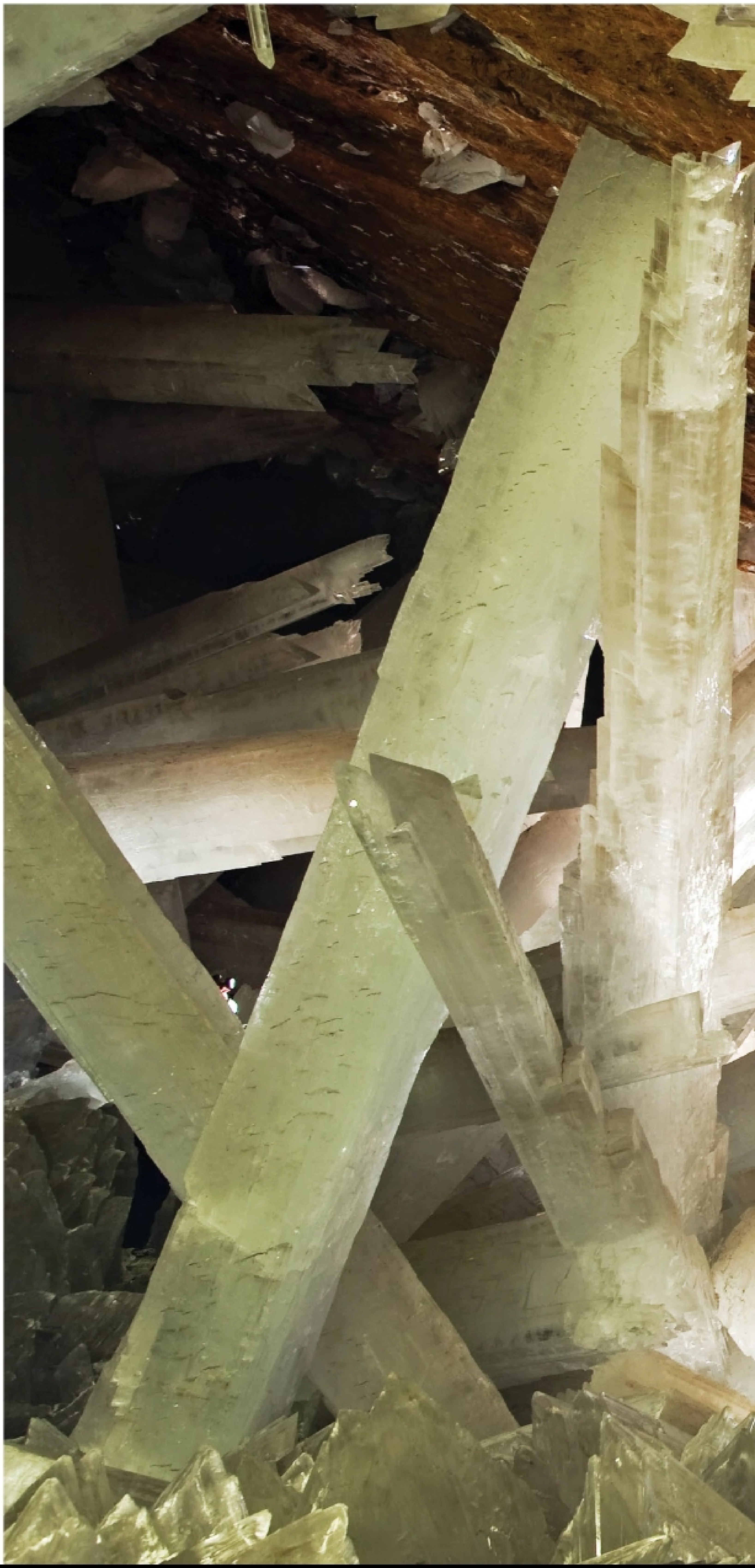
Deep under a Mexican desert lies a mysterious cave that's beautiful but deadly

Two brothers were drilling in the Naica mine in Mexico when they uncovered a geological wonder of the world, hundreds of thousands of years in the making. The Cueva de los Cristales, or Cave of Crystals, is a glittering palace covered in some of the largest crystals anyone has ever seen. Measuring over 11 metres – roughly the length of a bus – they have thrived in the extreme conditions of the cave.

Temperature is a sweltering 44 degrees Celsius and up to 100 per cent humidity means the air you breathe quickly condenses inside your lungs. Geologists hell bent on exploring the cave and living to tell the tale had to don specially designed suits, strewn with ice packs. If they had taken their respirator mask off for more than ten minutes, they would have fallen unconscious. However, what proves deadly for humans are actually the perfect conditions for growing crystals.

These monstrous structures are made of a soft mineral called selenite, and formed from groundwater saturated with calcium sulphate, which was heated by a magma chamber below. As the magma cooled, the minerals in the water started to transform into selenite and steadily built up. The cave's oldest resident is 600,000 years old – forming at the time when the ancestors of modern humans first appeared!

The crystals only stopped growing when miners unintentionally drained the cave in 1985 while they lowered the water table. But when the mine stops being profitable, the owners of the Naica mine will remove the pumps and the cave will flood once more. The crystals will be lost, but we can take comfort in knowing there must be more hidden marvels like this. "We know more about the outer edges of the Solar System than we do about the first kilometre of the Earth's crust," Professor Iain Stewart told the BBC after exploring the caves. "We can be sure there will be discoveries even more spectacular than Naica."



"The cave's oldest resident is 600,000 years old"

© Getty

Why do rivers meander?

Find out what factors cause rivers to curve

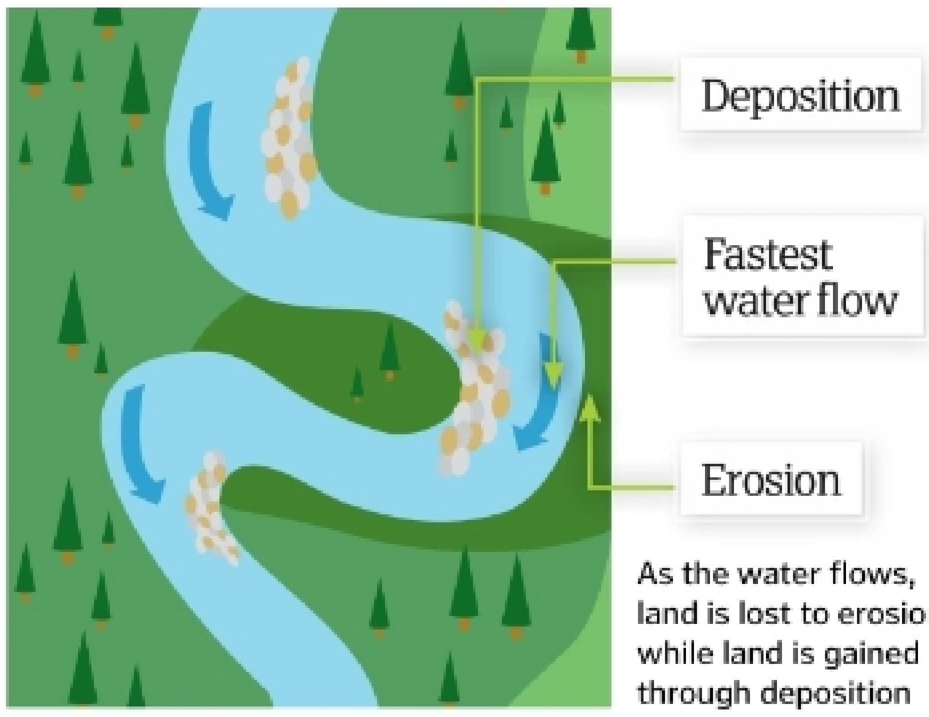
The winding curve or bend in a river is the result of erosional and depositional processes. River water flows around various obstructions, such as stones and rocks, which results in different areas of slow- and fast-moving water.

Deeper parts of the river contain slower areas of water and are filled with fine sediments. These parts are known as pools. Shallower parts of the river contain faster areas of water and larger stones. These areas are called riffles. The river flow swings from side to side and, over time, the pools move to opposite sides of the relatively straight channel.

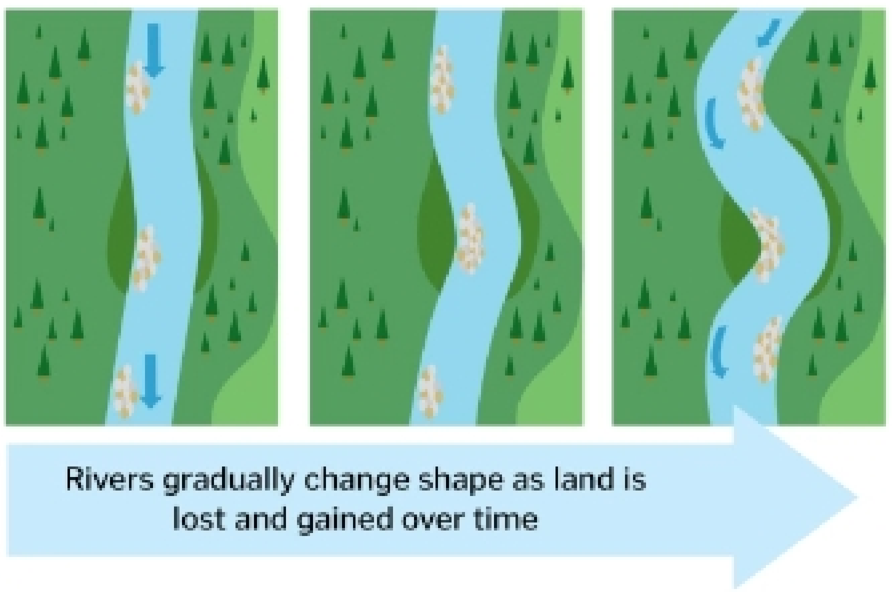
As fast-flowing water erodes the outside of the pool and slow-flowing water deposits various materials on the inside of the pool, meanders begin to occur.

How does a meander form?

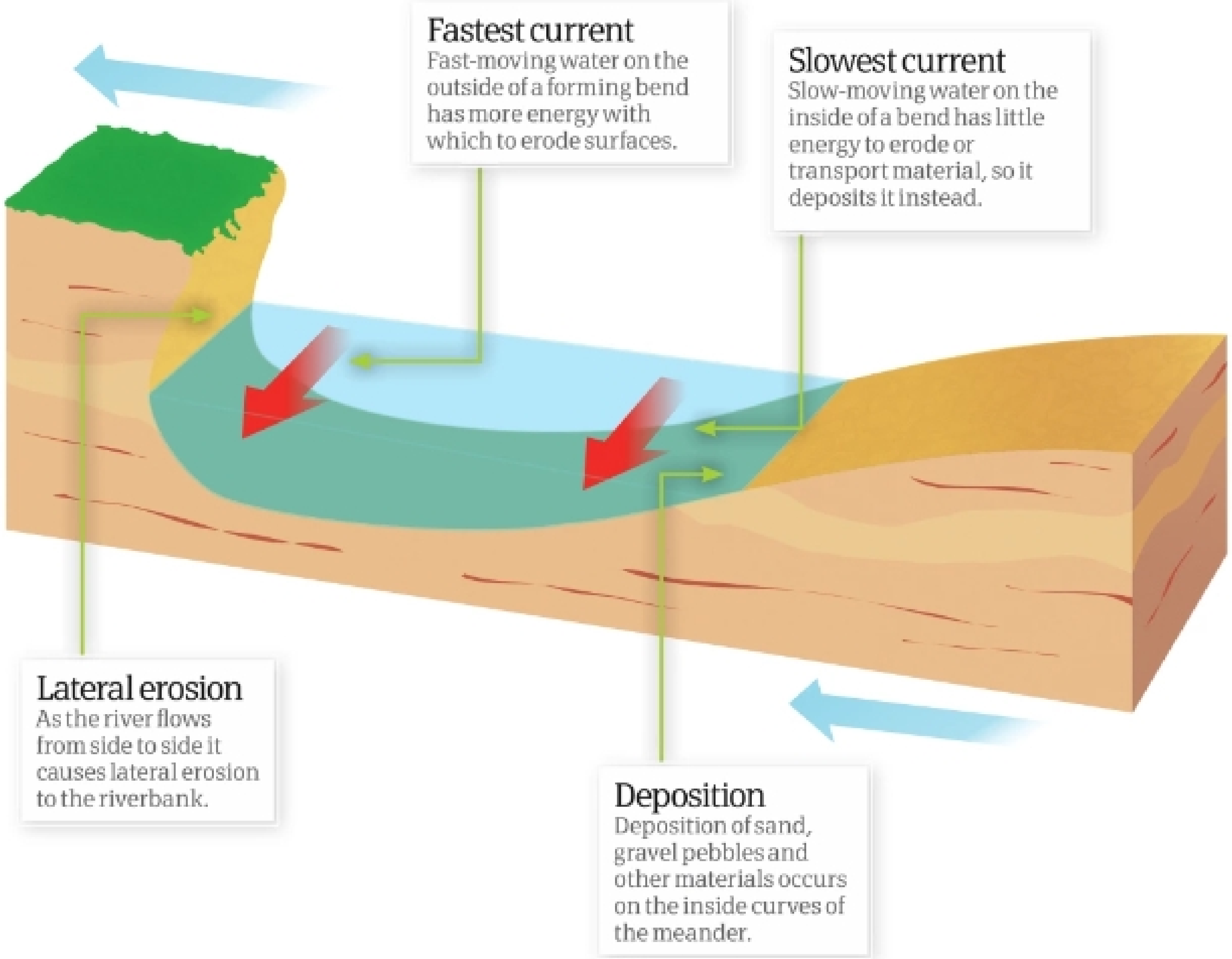
Take a look at the processes that create a winding river



As the water flows, land is lost to erosion while land is gained through deposition



Rivers gradually change shape as land is lost and gained over time



Fastest current
Fast-moving water on the outside of a forming bend has more energy with which to erode surfaces.

Slowest current
Slow-moving water on the inside of a bend has little energy to erode or transport material, so it deposits it instead.

Lateral erosion
As the river flows from side to side it causes lateral erosion to the riverbank.

Deposition
Deposition of sand, gravel pebbles and other materials occurs on the inside curves of the meander.

What is a soybean plant?

Introducing the most important bean in the world

The soybean plant is an erect branching plant that can grow to more than two metres high. It thrives in warm, fertile, well-drained sandy loam. The flowers are self-fertilising, white or purple in colour, and there are up to four seeds per pod, which are mostly brown in colour.

The soybean is an annual legume of the pea family. As one of the richest and cheapest sources of protein, it provides vegetable protein and ingredients for hundreds of chemical products, making it economically the most important bean in the world.

Commonly consumed as soy milk and tofu, the beans can also be eaten as a vegetable in salads and other meals, or crushed and fermented to produce soy sauce and miso. Its oil can be processed into margarine, shortening and vegetarian cheeses, and even used industrially in paints, adhesives and more.

Botanists generally claim that the soybean plant was domesticated around 7,000 BCE in China. However, although it's been used in the east as a food and a medicine component for thousands of years, the west has only been aware of its nutritional value for the last 250 years.

The soybean plant can be cultivated in most types of soil

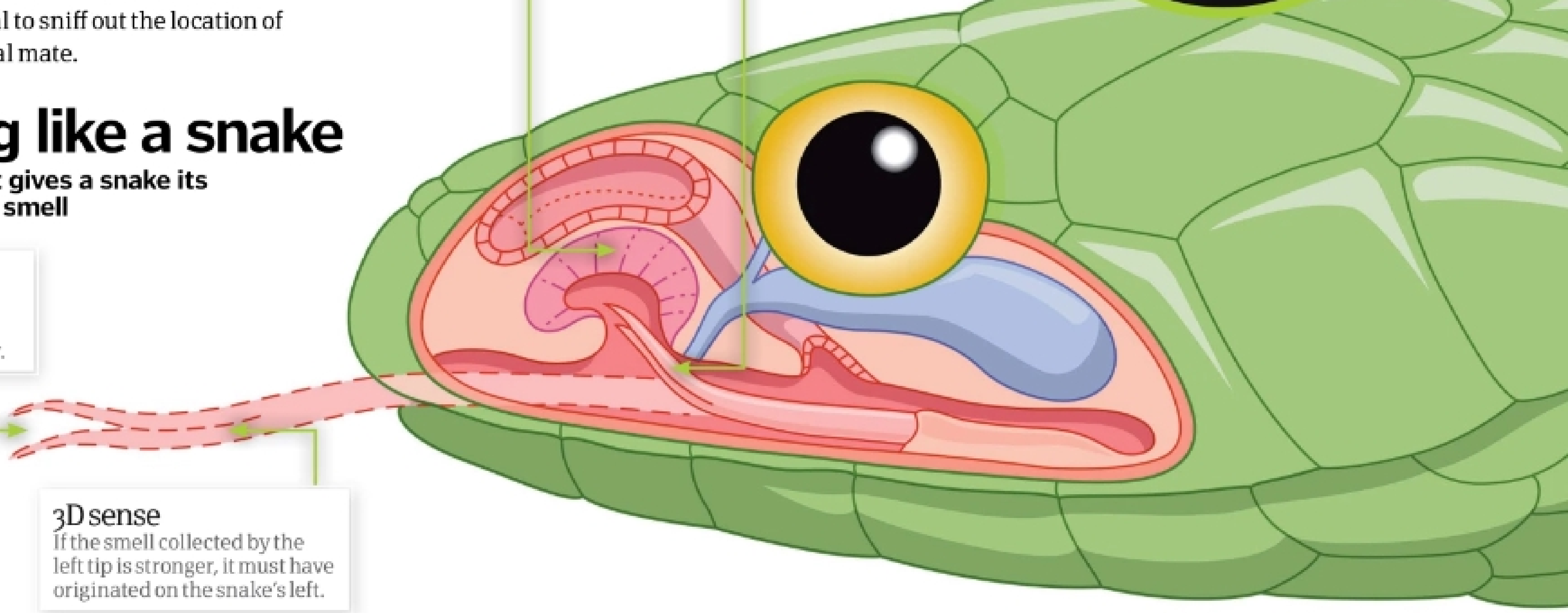
Do snakes need two tongue tips?

Discover the secret behind a snake's three-dimensional sixth sense

Just as humans have two ears to help them locate the source of a sound, snakes and some lizards have two tongue tips to help them work out the origin of a smell. However, it's not the tongue itself that detects the smell. Instead it transports the odour particles to a vomeronasal organ inside the reptile's mouth, which helps a sensory organ work out what the smell is and where it is coming from. As most reptiles also have noses, this ability is not a replacement for smelling, but serves as an extra sense that makes it easier for the animal to sniff out the location of its prey or a potential mate.

Smelling like a snake

The anatomy that gives a snake its superior sense of smell



Vomeronasal organ
The snake runs its tongue along two thin grooves on the roof of its mouth.

Sensory organ
A small sensory organ can detect the odour-producing chemicals in the air.

Dual tips
The two forks of the tongue collect scent particles from the air.

3D sense
If the smell collected by the left tip is stronger, it must have originated on the snake's left.

Why do whales become beached?

The mystery of why whales become stranded on the shore

Finding large groups of whales stuck on beaches is becoming a more common occurrence across the world. Experts don't have one clear reason to explain why, but they do have several theories.

It could just be that illness, injury, genetic mutation or even old age leaves the whales too weak to resist currents that push them ashore. Alternatively, changes in the whales' environment, such as bad weather, rising ocean temperatures or pollution could cause them to become lost, or they may simply follow prey into the shallows and become trapped by a low tide.

Another theory involves ship technology. In 2001 a study found a correlation between mass whale strandings and the use of underwater sonar by navies to detect submarines. As whales also use these sound waves to navigate, they could be causing them to become disorientated.

Very social animals , whales often travel in groups called pods, and it's likely that when one becomes stranded, the rest of its pod will naturally follow or perhaps try to come to its rescue, resulting in a mass beaching. But things may improve. In July 2016 a US court banned the use of a sonar system that harmed marine life.

Whales cannot survive out of the water for long, so beaching is very dangerous for them

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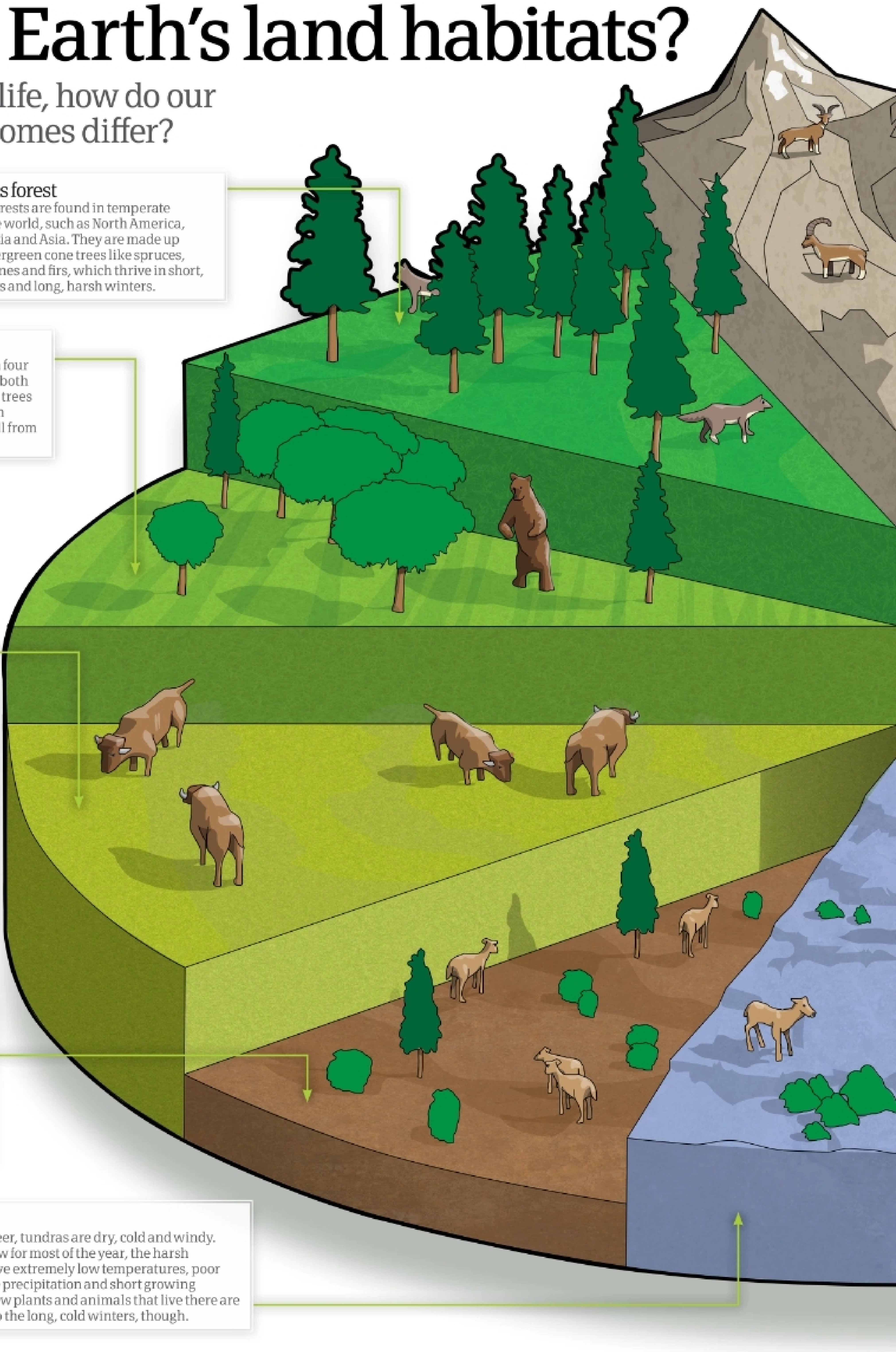
What are Earth's land habitats?

From climate to wildlife, how do our planet's incredible biomes differ?



Coniferous forest
Coniferous forests are found in temperate regions of the world, such as North America, Europe, Russia and Asia. They are made up mainly of evergreen cone trees like spruces, hemlocks, pines and firs, which thrive in short, cool summers and long, harsh winters.

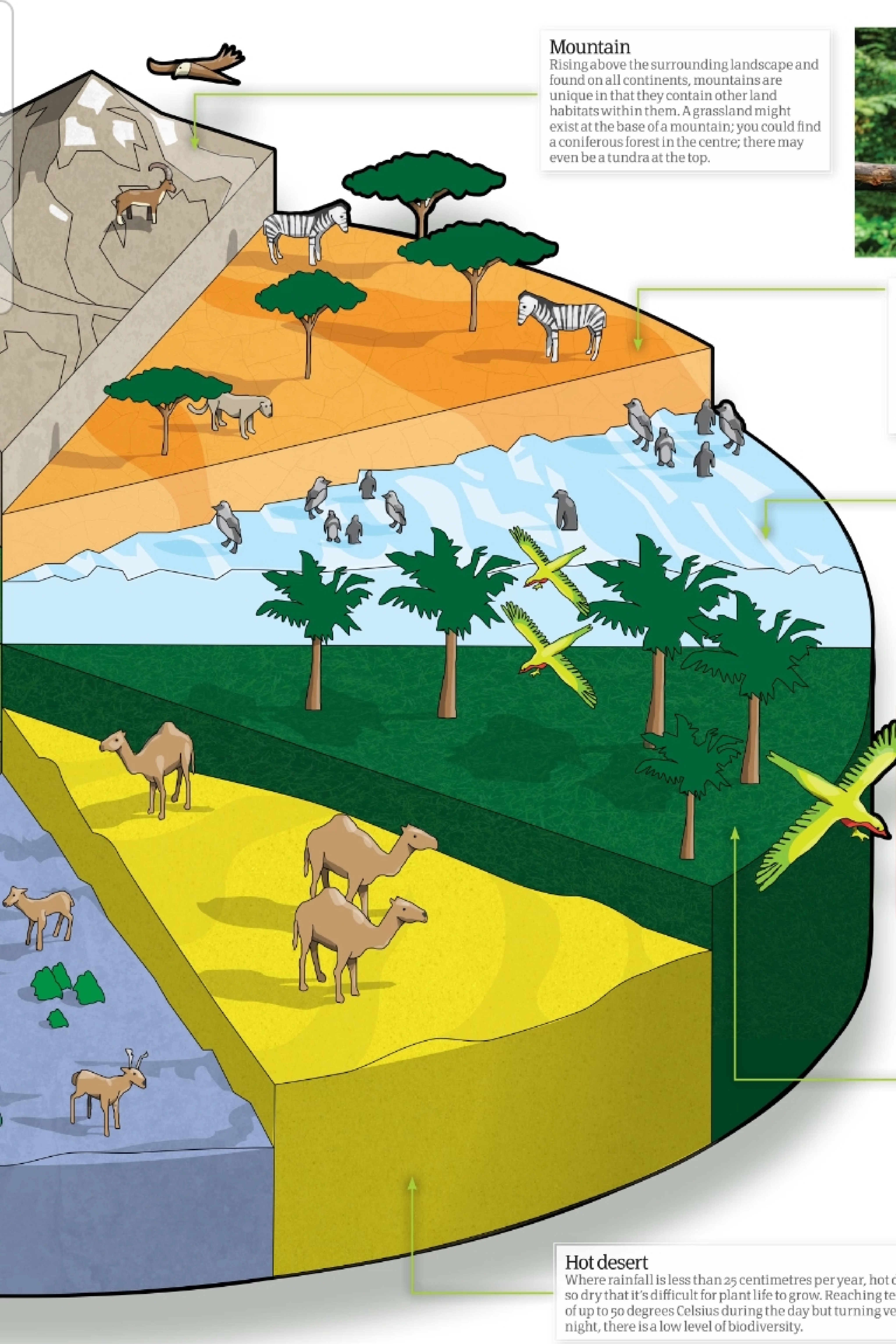
Deciduous forest
Deciduous forests exist in areas that go through four distinct seasons, so wildlife adapt to survive in both warm summers and cold winters. For example, trees have thick bark to protect them from the cold. In autumn, the leaves change colour; they then fall from the trees in winter and grow back in spring.

Temperate grassland
Lacking in trees and shrubs, the dry grasslands of Africa (veldts), North America (prairies), South America (pampas) and Eurasia (steppes) have nutrient-rich soils that are ideal for grazing animals. Although home to many animals, such as bison and antelope, there is little diversity in terms of wildlife.

Polar ice habitats are covered in ice for most of the year

Mediterranean
Mediterranean habitats have hot and dry summers, but cool and moist winters. Experiencing low rainfall, but still more than in desert regions, many animals and plants have adapted to survive in these conditions. These ecosystems are teeming with insect species, and home to plants that have adapted to conserve water.

Tundra
Home to reindeer, tundras are dry, cold and windy. Covered in snow for most of the year, the harsh landscapes have extremely low temperatures, poor nutrients, little precipitation and short growing seasons. The few plants and animals that live there are well adapted to the long, cold winters, though.



Mountain
Rising above the surrounding landscape and found on all continents, mountains are unique in that they contain other land habitats within them. A grassland might exist at the base of a mountain; you could find a coniferous forest in the centre; there may even be a tundra at the top.

Savanna
Comprised of tropical grasslands, the open landscape of a savanna is littered with shrubs and isolated trees. Despite having a wet and dry season, savannas have warm temperatures all year round. Perfect for herbivores, such as elephants and zebras, animal types vary depending on where in the world the savanna is.

Polar ice
Covered in ice for most of the year, the Arctic and Antarctica in the North and South Poles are the coldest regions on Earth. Marine animals populate the waters, while polar bears and penguins live on land, in the north and south respectively. The only plant life is algae.

There is little in the way of biodiversity in the desert

Tropical rainforest
Home to more animal and plant life than any other habitat, tropical rainforests experience a constant hot temperature and high rainfall. Near to the equator and therefore exposed to plenty of sunlight, the humidity and dense vegetation provide a unique water and nutrient cycle.

Hot desert
Where rainfall is less than 25 centimetres per year, hot deserts are so dry that it's difficult for plant life to grow. Reaching temperatures of up to 50 degrees Celsius during the day but turning very cold at night, there is a low level of biodiversity.

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How do we predict the weather?

Discover the method that helps us prepare for the elements, come rain or shine

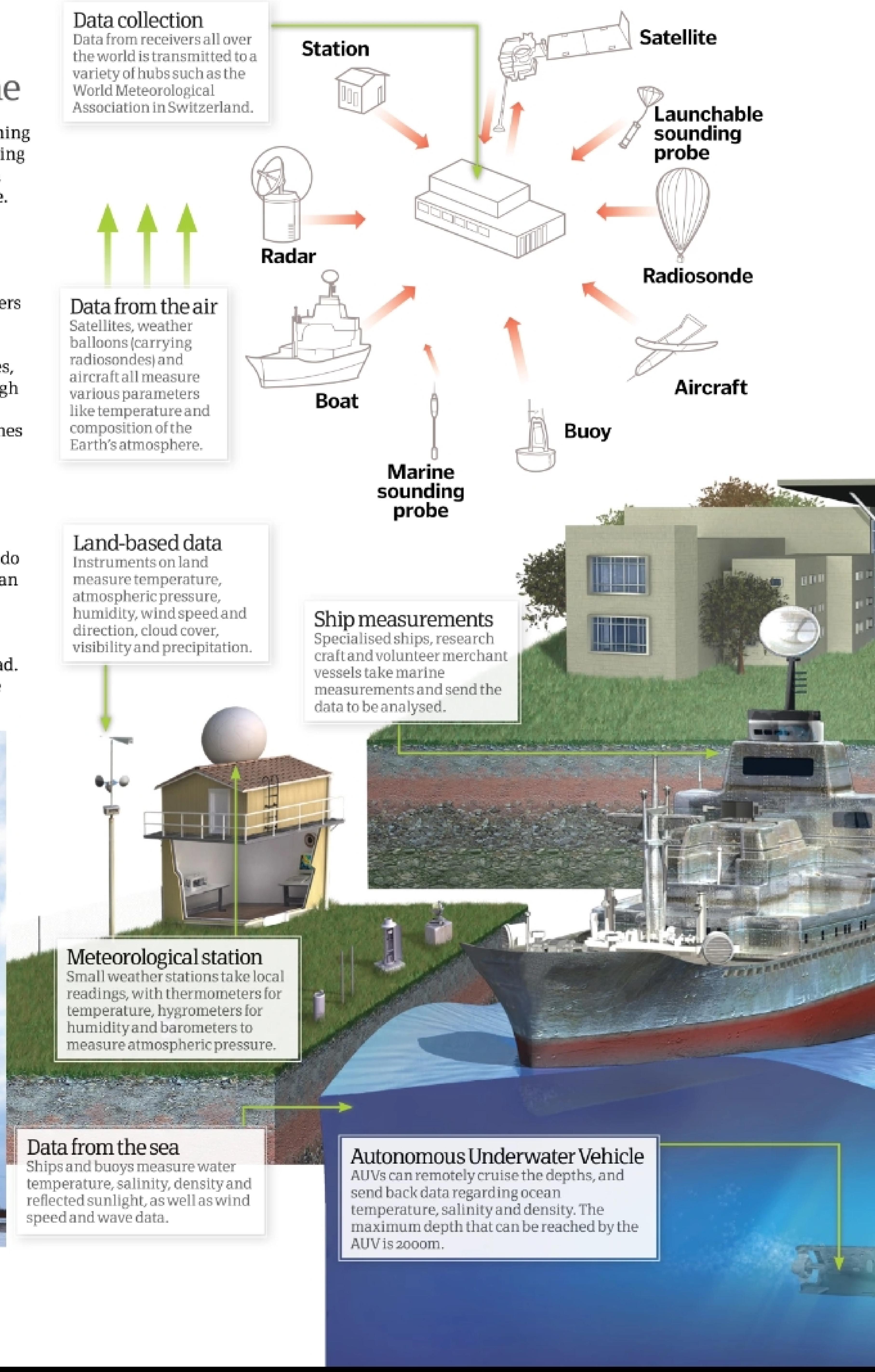
The weather affects us all, every day. From governing the difference between life and death, to providing a conversation topic to fill awkward silences at a party, it is an ever-present and ever-changing part of life. This means that predicting it accurately is a hugely important task.

In the UK, the Met Office is responsible for weather monitoring and prediction. Before a forecast can be put together, measurements from thousands of data recorders across the world are collected and analysed. Every day, around 500,000 observations are received, including atmospheric measurements from land and sea, satellites, weather balloons and aircraft. But, this is still not enough to represent the weather in every location.

To fill in the gaps, the data is assimilated. This combines current data with what is expected, to provide the best estimate of the atmospheric conditions. To produce an accurate forecast, the data has to be fed into a supercomputer that creates a numerical model of the atmosphere. The process involves many complex equations, and the Met Office's IBM supercomputer can do more than 1,000 trillion calculations a second, running an atmospheric model with a million lines of code.

Forecasters can use this data and techniques such as nowcasting – using estimates of current weather speed and direction – to predict the weather in the hours ahead. For longer range forecasts, further computer models are relied upon.

Thousands of small weather stations across the world feed data back to meteorological hubs



Data collection
Data from receivers all over the world is transmitted to a variety of hubs such as the World Meteorological Association in Switzerland.

Data from the air
Satellites, weather balloons (carrying radiosondes) and aircraft all measure various parameters like temperature and composition of the Earth's atmosphere.

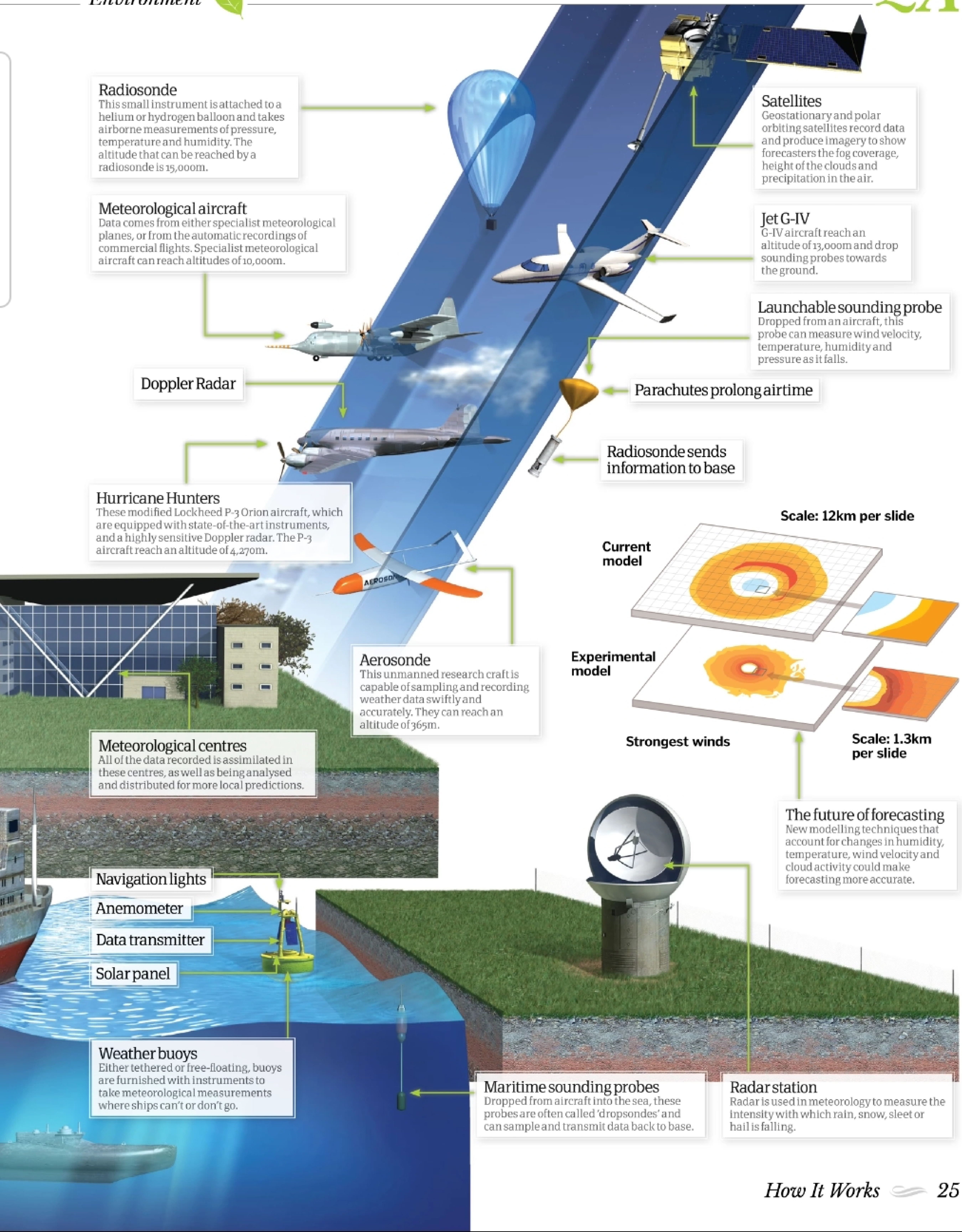
Land-based data
Instruments on land measure temperature, atmospheric pressure, humidity, wind speed and direction, cloud cover, visibility and precipitation.

Ship measurements
Specialised ships, research craft and volunteer merchant vessels take marine measurements and send the data to be analysed.

Meteorological station
Small weather stations take local readings, with thermometers for temperature, hygrometers for humidity and barometers to measure atmospheric pressure.

Data from the sea
Ships and buoys measure water temperature, salinity, density and reflected sunlight, as well as wind speed and wave data.

Autonomous Underwater Vehicle
AUVs can remotely cruise the depths, and send back data regarding ocean temperature, salinity and density. The maximum depth that can be reached by the AUV is 2000m.



Radiosonde
This small instrument is attached to a helium or hydrogen balloon and takes airborne measurements of pressure, temperature and humidity. The altitude that can be reached by a radiosonde is 15,000m.

Satellites
Geostationary and polar orbiting satellites record data and produce imagery to show forecasters the fog coverage, height of the clouds and precipitation in the air.

Meteorological aircraft
Data comes from either specialist meteorological planes, or from the automatic recordings of commercial flights. Specialist meteorological aircraft can reach altitudes of 10,000m.

Jet G-IV
G-IV aircraft reach an altitude of 13,000m and drop sounding probes towards the ground.

Launchable sounding probe
Dropped from an aircraft, this probe can measure wind velocity, temperature, humidity and pressure as it falls.

Hurricane Hunters
These modified Lockheed P-3 Orion aircraft, which are equipped with state-of-the-art instruments, and a highly sensitive Doppler radar. The P-3 aircraft reach an altitude of 4,270m.

Aerosonde
This unmanned research craft is capable of sampling and recording weather data swiftly and accurately. They can reach an altitude of 365m.

Meteorological centres
All of the data recorded is assimilated in these centres, as well as being analysed and distributed for more local predictions.

The future of forecasting
New modelling techniques that account for changes in humidity, temperature, wind velocity and cloud activity could make forecasting more accurate.

Weather buoys
Either tethered or free-floating, buoys are furnished with instruments to take meteorological measurements where ships can't or don't go.

Maritime sounding probes
Dropped from aircraft into the sea, these probes are often called 'dropsondes' and can sample and transmit data back to base.

Radar station
Radar is used in meteorology to measure the intensity with which rain, snow, sleet or hail is falling.

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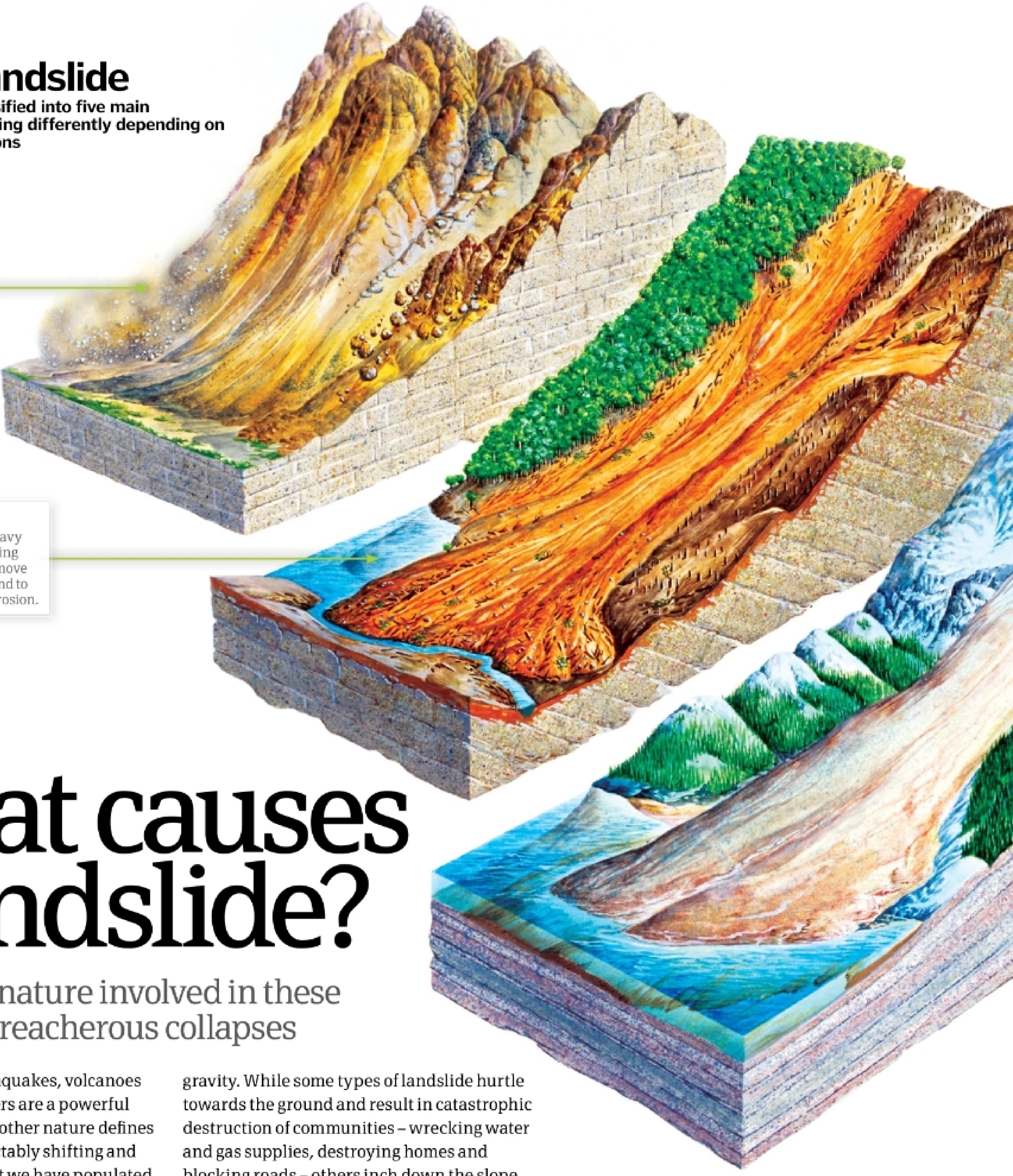
Types of landslide

Landslides can be classified into five main categories, each behaving differently depending on the terrain and conditions



Rock fall
This is the fastest type of landslide and involves rocks rapidly and suddenly falling from a cliff or steep slope. The loss of ground support can be caused by ice wedging, root growth or ground shaking.

Debris slide
These are often caused by heavy rain or rapid snowmelt, causing soil and fragmented rock to move down a steep slope. These tend to occur in areas undercut by erosion.

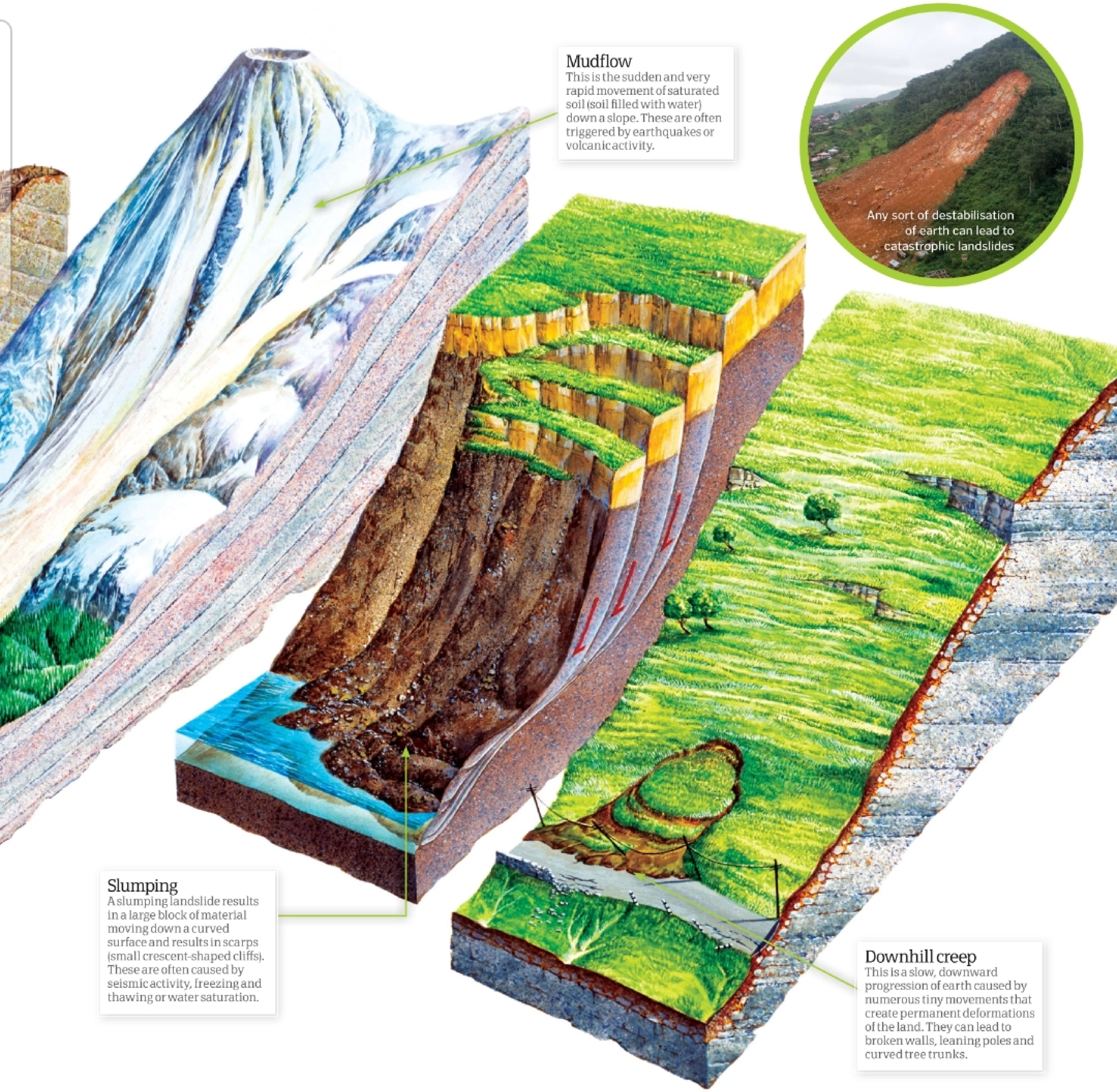
What causes a landslide?

The forces of nature involved in these sudden and treacherous collapses

Avalanches, earthquakes, volcanoes – natural disasters are a powerful reminder that mother nature defines our landscape. Unpredictably shifting and shaping the habitats that we have populated, these events can cause wide-scale devastation and dramatic changes on the Earth's surface. Landslides are one of these natural disasters.

The term 'landslide' describes a category of mass movement that happens on cliffs and mountain faces. They occur when the rock, earth and debris clinging to the side of a mountain or slope succumb to the forces of gravity. While some types of landslide hurtle towards the ground and result in catastrophic destruction of communities – wrecking water and gas supplies, destroying homes and blocking roads – others inch down the slope over the course of years. Seismic activity and weather conditions like extreme rainfall have been shifting soil for millennia, but increased human activity means they are occurring even more frequently.

One of the most commonly observed causes of landslides occurs when cliffs or mountains become heavily saturated. The soil can slip more easily in areas of deforestation, for example, because the lack of trees means that there is no root system to protect against erosion. Clear-cutting methods of timber harvesting, which pull up existing root structures, increase the likelihood of a landslide occurring. Mining with detonation techniques, which generates strong vibrations that shudder through the ground, can also enhances the risk of a landslip.



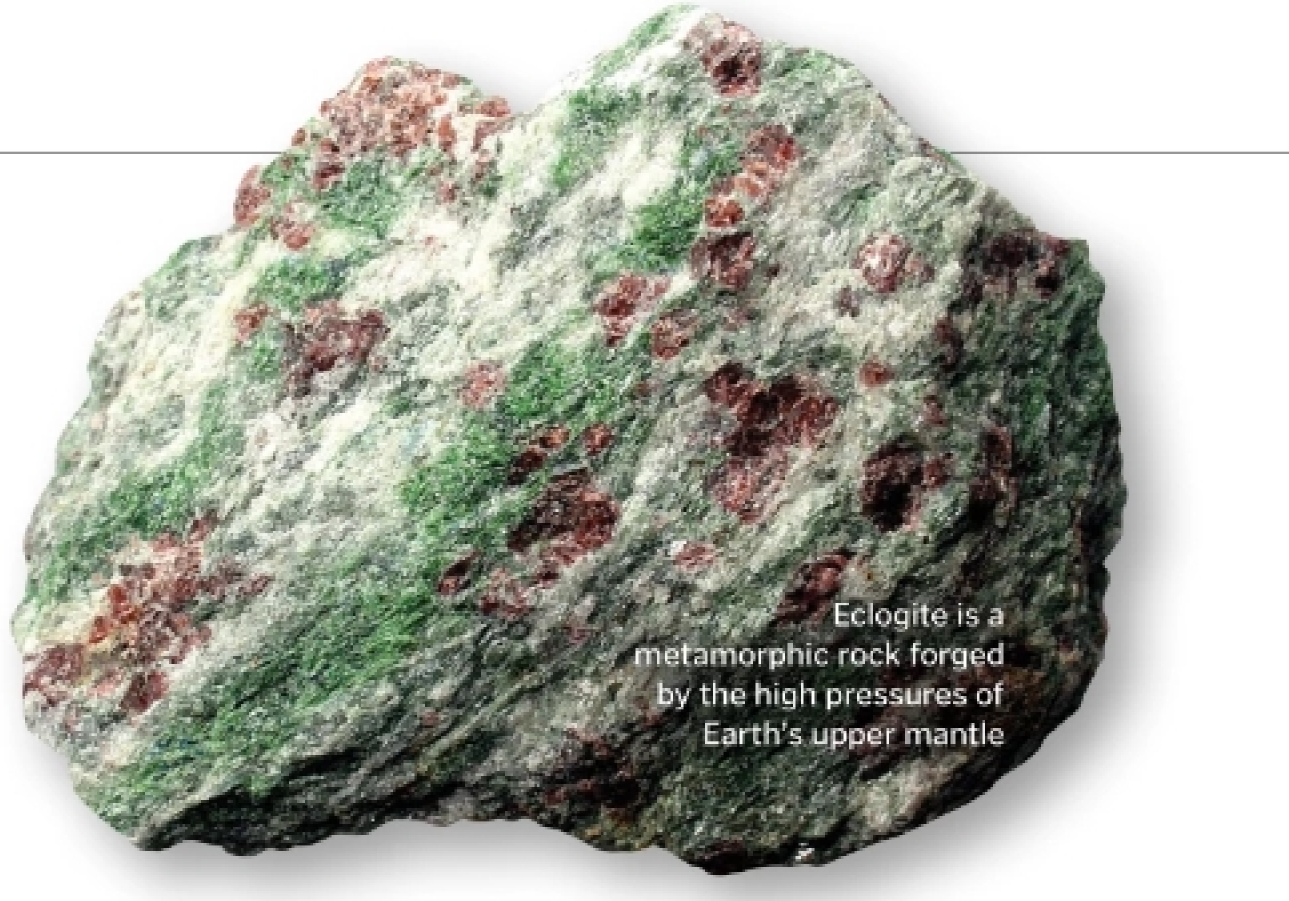
Mudflow
This is the sudden and very rapid movement of saturated soil (soil filled with water) down a slope. These are often triggered by earthquakes or volcanic activity.

Slumping
A slumping landslide results in a large block of material moving down a curved surface and results in scarps (small crescent-shaped cliffs). These are often caused by seismic activity, freezing and thawing or water saturation.

Downhill creep
This is a slow, downward progression of earth caused by numerous tiny movements that create permanent deformations of the land. They can lead to broken walls, leaning poles and curved tree trunks.

Any sort of destabilisation of earth can lead to catastrophic landslides

> “Landslides occur when the rock, earth and debris clinging to the side of a mountain succumb to the forces of gravity”



Eclogite is a metamorphic rock forged by the high pressures of Earth's upper mantle

How are rocks recycled?

How the rocks on our planet are weathered, worn and transformed countless times

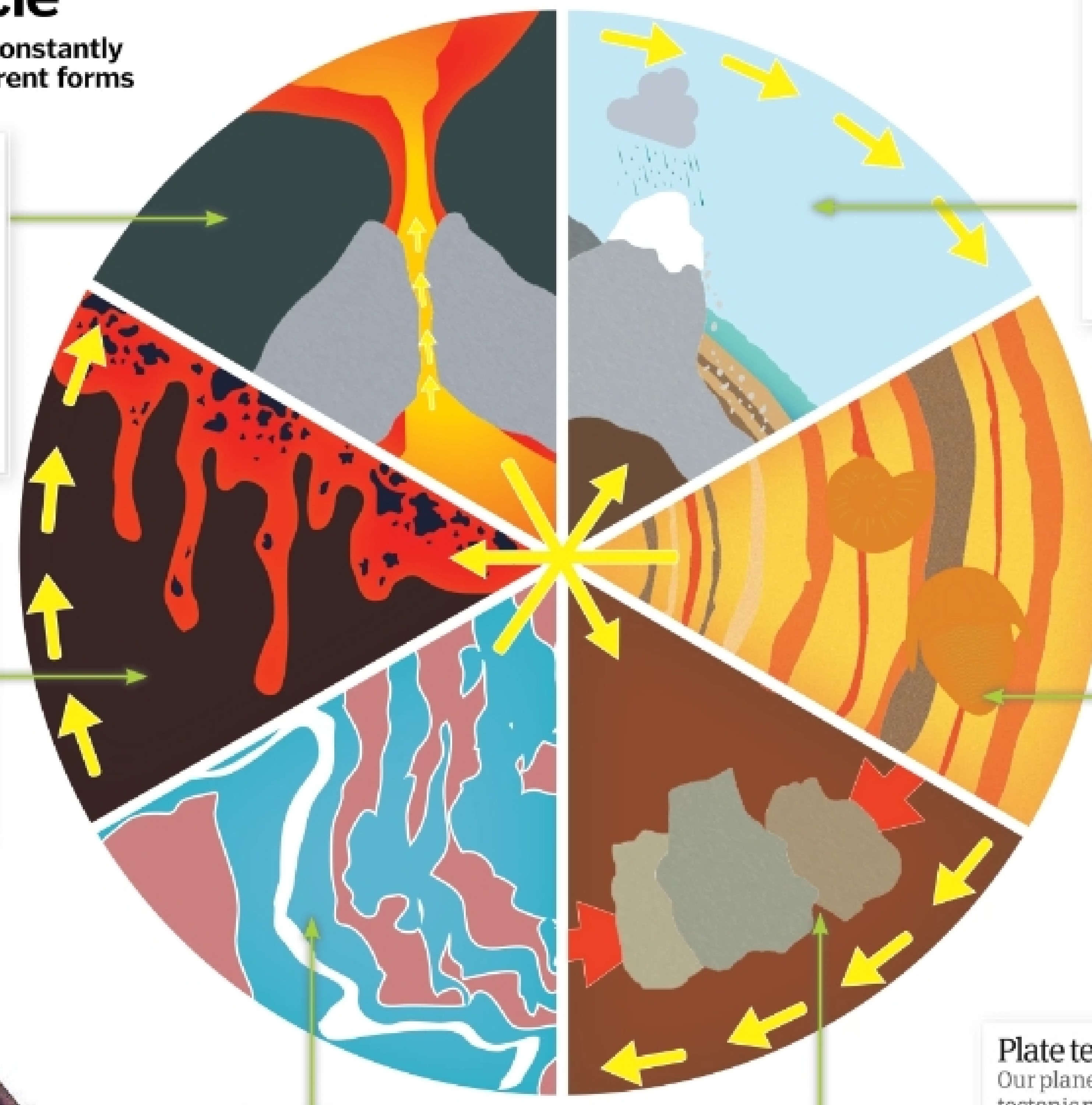
Our planet is covered with different types of rock, from great mountains to molten magma to grains of sand – and all of these forms are connected by the rock cycle. This model shows how the three main classifications of rock – igneous, sedimentary and metamorphic – are able to morph into one another as different forces act upon them.

Wind, rain, snow and ice gradually erode mountains and cliffs to provide the material that will eventually be compacted to become sedimentary rock. The internal structure of our planet itself also plays an important role. The mantle – a 2,900-kilometre-thick, semi-molten region found beneath the Earth's crust – provides extreme heat and pressure that compact rock into a metamorphic form. The planet's core generates intense heat that melts the lower mantle into magma. This magma becomes igneous rock as it cools, either at the Earth's crust or above the surface when it is ejected in volcanic eruptions.

The rock cycle is a story of rebirth and recycling, where the old provides materials for the new. The cycle takes thousands if not millions of years, but we can see snapshots of the process: waves crashing against rocks, shifting glaciers and dramatic volcanic eruptions all provide glimpses of the processes that govern Earth's ever-changing geology.

The rock cycle

The forces of nature are constantly morphing rocks into different forms



Igneous rock
Igneous, which means 'born of fire or heat', is the rock type formed when molten magma cools enough to become solid. Intrusive igneous rock forms when the magma cools slowly under the Earth's surface, and extrusive igneous rock forms when the magma cools rapidly on the surface, such as after a volcanic eruption.

Weathering and erosion
Weather conditions such as heat, wind, rain, snow and ice take their toll on mountains and cliffs, and the rocks are slowly eroded, breaking them into smaller fragments called sediments. These are then carried away within bodies of water, such as streams and rivers.

Rising heat
The intense heat found below the surface – sometimes stemming from the planet's superheated core – can generate temperatures up to 1,300 degrees Celsius, causing rock to melt into a molten form called magma, which rises towards the cooler surface via convection.

Sedimentary rock
When sediments eventually settle, they are deposited in layers that accumulate over millions of years. The weight of the layers compresses the sediments at the bottom, squeezing out water and enabling crystals to form. These crystals act a bit like cement, gluing the pieces of rock together.

Metamorphic rock
The combination of intense pressure and high temperatures (between 300 and 700 degrees Celsius) doesn't melt rocks, but changes their chemical structure. They are transformed into dense metamorphic rock.

Plate tectonics
Our planet's crust is formed of tectonic plates, which are always moving very slowly. When these plates collide, mountains are formed and earthquakes are generated, and the friction also results in huge amounts of heat and pressure below the surface.

© Siim

The igneous rock obsidian forms when lava cools so rapidly that atoms are unable to form crystals

What causes wind patterns?

Wind paths, ocean currents and even airplanes are governed by the same invisible force

The tell-tale spiral of 2011's hurricane Katia is whipped up, aided by the Coriolis effect

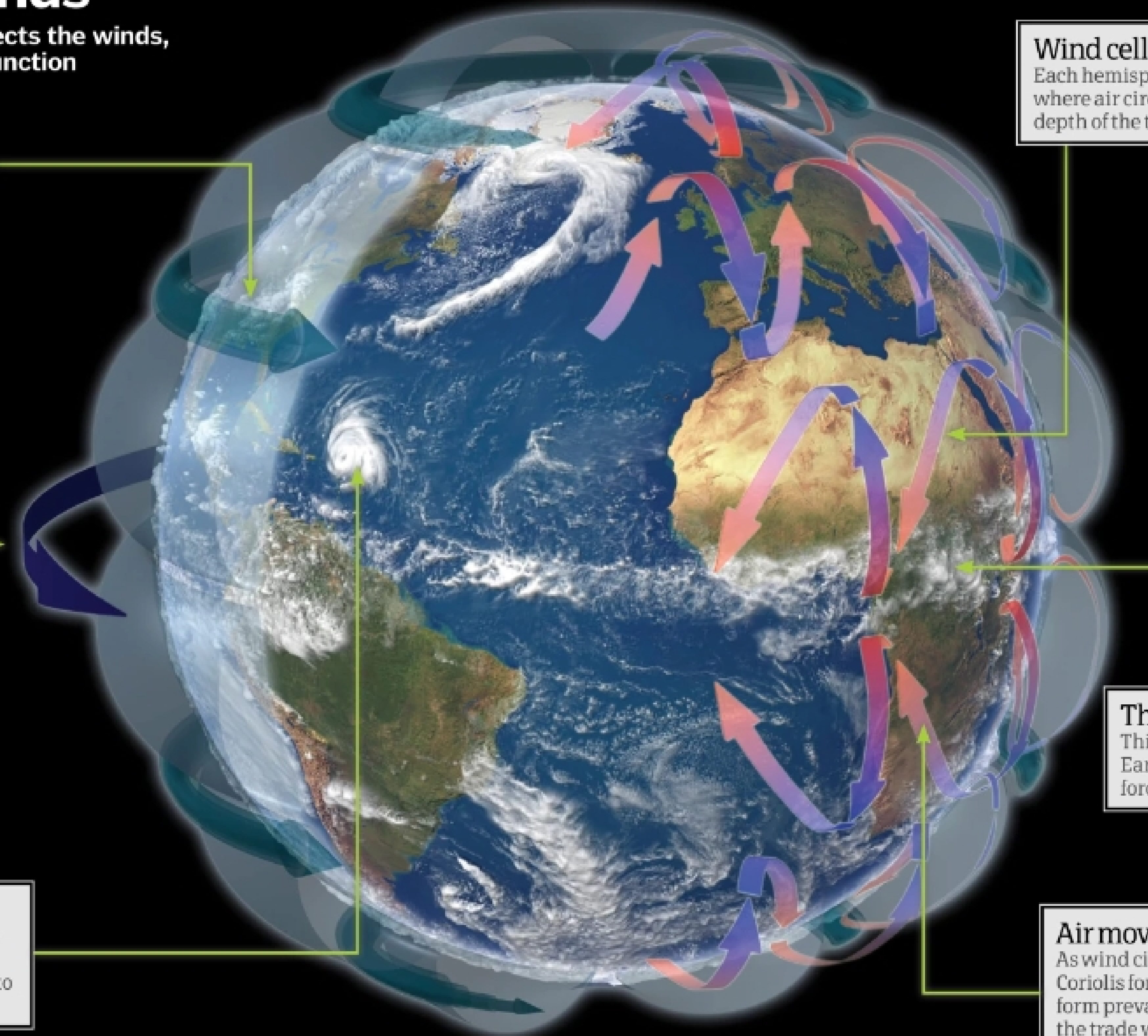
Winds in our atmosphere do not travel in straight lines due to a phenomena known as the Coriolis effect. As the Earth spins on its axis, the motion deflects the air above it. The planet's rotation is faster at the equator, because this is where the Earth is widest. This difference in speed causes the deflection – for example, if you were to throw a ball from the equator to the North Pole it would appear to curve off-course. If Earth didn't spin like this, air on the planet would simply circulate back and forth between the high-pressure poles and the low-pressure equator. When the rotation of the Earth is added into the mix, it causes the air in the Northern Hemisphere to be deflected to the right, and air in the Southern Hemisphere to the left, away from the equator. As a result, winds circulate in cells.

It's this effect that causes the rotational shapes of large storms that form over oceans. The low pressure of cyclones sucks air into the centre, which then deflects thanks to the Coriolis force. This explains why cyclones that form in the Northern Hemisphere spin anti-clockwise, while in the Southern Hemisphere they rotate clockwise. The opposite is true of high pressure storms, or anticyclones, which rotate clockwise in the north and anti-clockwise in the south.

The Coriolis effect is so prevalent that it also governs the movement of long-range airborne objects such as airplanes and missiles. Pilots have to adjust their flight routes to compensate for the deflection.

Global winds

How Earth's spin affects the winds, their direction and function



Jet streams
High-altitude jet streams flow between cells. They are strong winds that move weather systems.

Earth spins
At the equator, the Earth is spinning at a speed of 1,670km/h.

Tropical hurricane
A tropical hurricane forms near the Caribbean. The Coriolis effect contributes to the swirling system.

Wind cells
Each hemisphere has three cells, where air circulates through the depth of the troposphere.

The equator
This is the only place on Earth where the Coriolis force is not felt.

Air movement
As wind circulates in cells, the Coriolis force deflects the air to form prevailing winds such as the trade winds.

© Science Photo Library, NASA

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What are the criteria for determining a new species?

Generally scientists consider a species to be new if it has its own gene pool and evolutionary lineage. If you think that you've discovered a new species, there's a long process to go through.

The first step is to get some specimens to compare against other species that are closely related. You collect all of the data about the species, then comb through the literature about related species to be sure that what you have doesn't match with any other description. Once you're reasonably sure that it's new, you publish the data in a peer-reviewed scientific journal so that others can learn about the species and help verify that it's new. Naming the species comes last, and there are rules here.

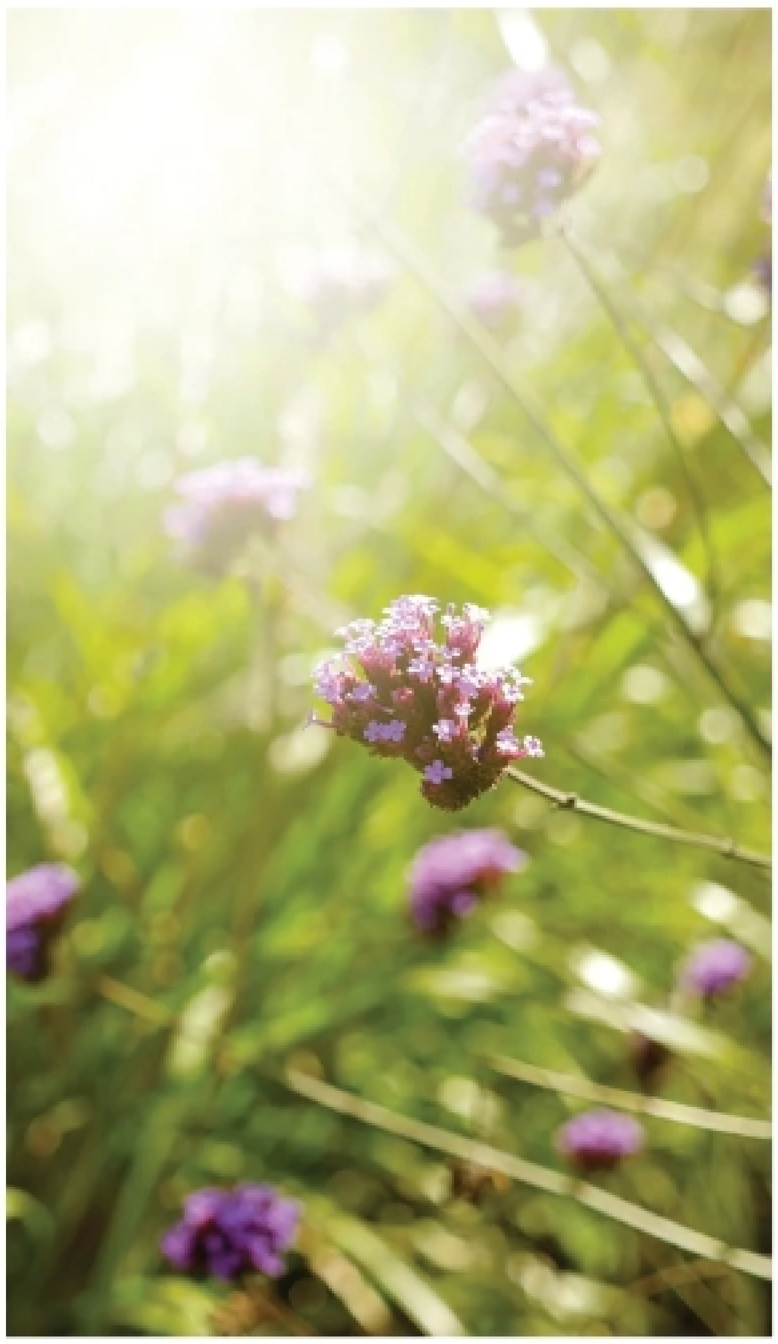
Depending on what type of species that you've discovered, you'll have to follow criteria set out by an international organisation, such as the International Commission on Zoological Nomenclature.

How do clouds float?

The tiny droplets and ice crystals that make up clouds are incredibly small and light, meaning that gravity has very little effect on them. For something to fall to the ground, the Earth's gravitational pull must be greater than the resistance an object encounters as it moves through the air. Just like particles of dust that float in the air, the droplets' surface area is great enough relative to their mass to keep them afloat. When tiny droplets within a cloud collide, they merge to form larger drops.

Could the Earth ever run out of oxygen?

Oxygen is continually being produced by plants and a variety of chemical processes, so it is very unlikely that we would ever run out of it. Plants (including tiny phytoplankton in the ocean) use the energy from sunlight to convert carbon dioxide and water into sugars and oxygen, a process called photosynthesis. This replenishes the oxygen used up by respiration or chemical reactions such as combustion. Even if plants stopped photosynthesising, we have enough stores of oxygen in our atmosphere to support human and animal life for at least a few hundred years.



> "We have enough stores of oxygen in our atmosphere to support human and animal life for a least a few hundred years"

Would polar bears be able to survive in Antarctica?

Discussions have taken place on relocating polar bears to Antarctica to aid their survival, due to significant sea-ice loss in the Arctic. However, although polar bears probably could survive in Antarctica, the disadvantages outweigh the advantages. Scientists have studied previous cases where animals have been relocated, and found that it's usually harmful to the overall ecosystem.

Seals and penguins currently have no land predators in Antarctica, but this would change if polar bears were introduced to their habitat – it could even result in their extinction. Throughout the food chain, the balance of resources such as space, water and food would be upset, and polar bears could introduce new diseases to native species, or face life-threatening diseases themselves.

So although polar bears would probably be able to survive in Antarctica, the move would be counterproductive for both them and other species.

* * *

Do underwater snakes have gills?

While some snakes spend time in water, sea snakes live there permanently. However, instead of gills, they have a single lung, and must surface to breathe about once an hour. Valves keep their nostrils, which sit on top of their snouts, closed the rest of the time. These snakes also absorb oxygen through their skin, and have small, flattened heads, and paddle-like tails to aid with swimming. Most species live in warm waters in the Indian and Pacific Oceans. Sea snakes have very potent venom and release small amounts when biting fish and other prey.

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Why is gooseberry jam red when gooseberries are green?

The gooseberry is a round, edible berry with a thin, translucent, hairy skin. Although green in colour, gooseberry jam is a shade of orange or red due to a pigment in the berry called anthocyanin. This pigment is present in many fruits, and can give them reddish, yellow or green colours, depending on the pH, or acidity, of the fruit. When you cook a gooseberry jam mixture, the anthocyanins are heated and come into contact with plant sugars such as pectin, as well as metal ions from cooking instruments. This process is thought to change the acidity and slightly alter the structure of the anthocyanins, and the jam changes colour as a result.

Why do cats only meow at humans?

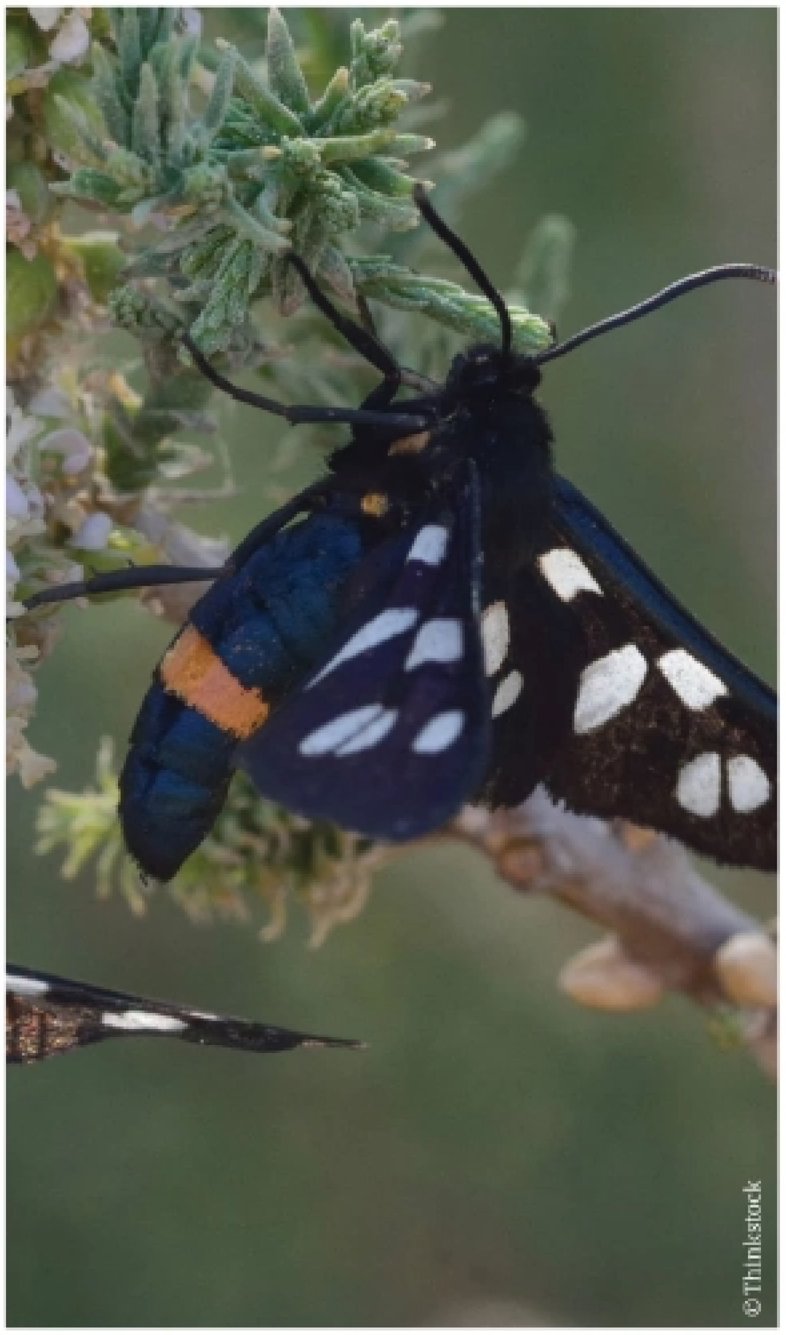
Cats only meow at each other as kittens; adult cats only meow at humans. That's because they've learned that we respond to it. Cats meow when they're hungry, need to go out, want your attention, or just want to say hello. Older cats or cats with mental disorders may also meow for no apparent reason. In general, though, they're meowing to let you know something, even if you can't always figure it out. Cats do yowl at each other – a long, extended form of meow – during mating or fighting

Is it true that elephants never forget?

Elephants do forget, but they have impressive memories. They have the largest brains of any land mammal, and some believe that their intelligence is up there with chimpanzees and dolphins. Elephants live for decades, and travel in family groups led by older females. To be successful, they need to be able to keep track of friends and enemies, and they need to navigate long distances over complicated terrain as the climate changes year after year. African elephants have been known to lead their families to long forgotten watering holes in times of drought, to remember injuries and mistreatment, and to recognise the clothing of people who have done them harm.

Why do we see lightning before we hear thunder?

We see lightning first because light travels faster than sound. Light travels at about 300,000 kilometres per second, while sound travels at about 0.34 kilometres per second, depending on air temperature. The flash of lightning superheats the air around its path almost instantly to temperatures greater than 25,000 degrees Celsius. As it moves outward, the hot air compresses the air around it and this expansion creates a shock wave, which then becomes a sound wave. We hear the sound waves as loud booms and cracks, or thunder.



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What is the powder on moth wings?

Both moths and butterflies have a powdery substance on their wings that's actually a type of modified hair called a scale. These scales are probably mostly for looks, contributing to the pattern and colour of the wings. However, they may also help moths to regulate their body temperature – dark colours absorb light better – or camouflage them from predators. They may even help moths to modify airflow as they fly. Losing some of the powder probably wouldn't stop the moth from flying, but it's important not to touch the wings; they are very fragile and can be easily damaged.

> "It's important not to touch the wings; they are very fragile and can be easily destroyed"

Technology

36 What will life be like in 2050?
44 How do keys open doors?
45 How do food blenders work?
46 How is waste turned into energy?
48 How are digital images captured?
49 How do wristwatches tick?
50 How do industrial robots work?
52 How does new tech fight fires?
54 Bitesize Q&A

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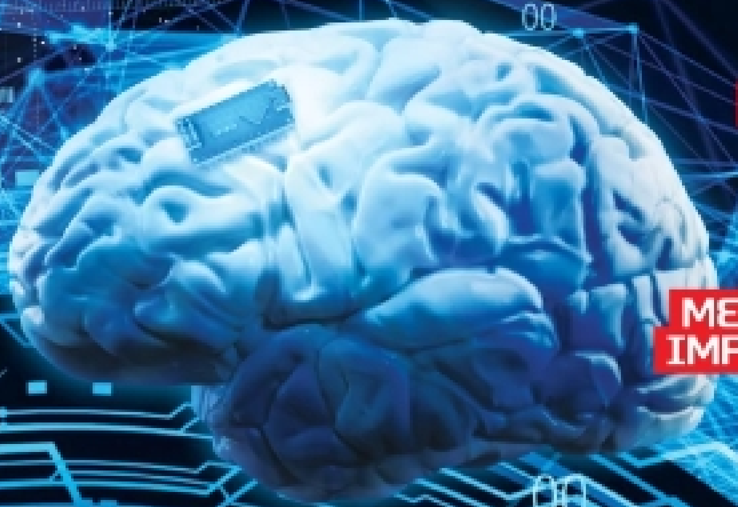
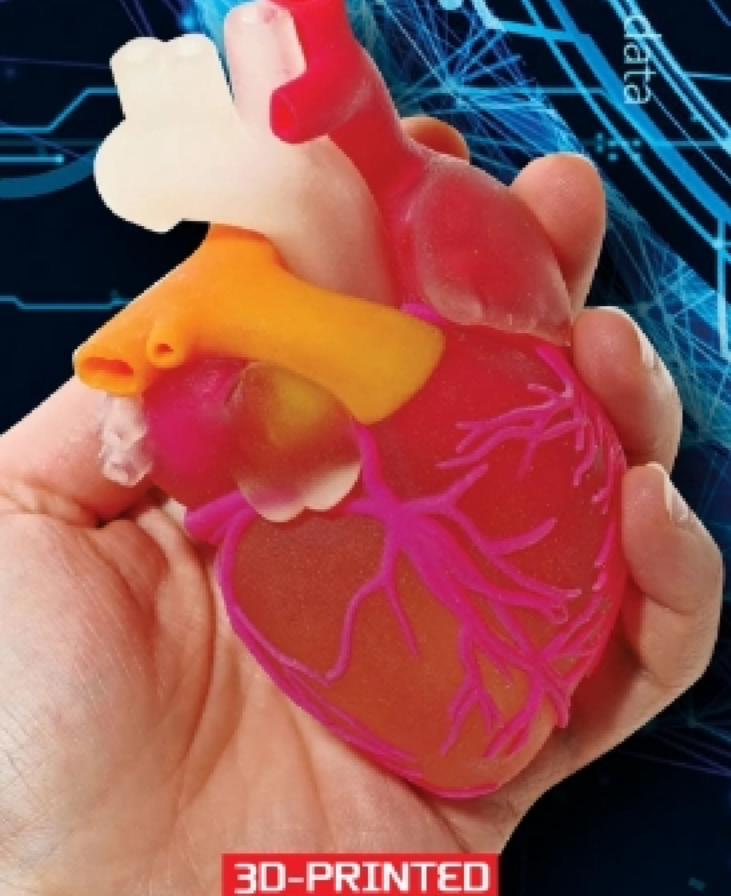


WHAT WILL LIFE BE LIKE IN 2050?

WELCOME TO THE WORLD OF THE NEXT GENERATION

Words by **James Horton**



Sprawling, eco-friendly megacities, a global population exceeding 9.8 billion, and far-reaching inventions that marry biology and technology all lay ahead of us. Today's world is one filled with ideas, innovation and imagination, making us perfectly poised to speculate on what the world will become in just over three decades.

It may seem dangerous to cast our eyes so far ahead, across decades of exponential progress. But in today's research we find the seeds of the era-defining technologies that will come to be. In the 1950s, Alan Turing considered the 'ghost in the machine' and challenged his contemporaries to consider whether we could truly create intelligent – if not sentient – machines. Now, with deep neural networks and other artificial intelligence approaches we find ourselves edging ever closer to an idea first posed over 60 years ago. Turing's vision has almost been realised, and within this feature we will uncover analogous ideas that may grow, just as Turing's vision did, into technologies that will bring similar disruption to the world of 2050.

MAKING NEW STRIDES

As the collective pool of human knowledge continues to expand, we will increasingly see branches of research broaden their perspective and bleed into different areas of investigation. Such fusions of science and technology will play a pivotal role in the years to come. For example, forensics may start incorporating the staggeringly broad applicability of data science. Researchers at Oxford University have for the first time uncovered genetic variations that are strongly associated with particular facial features. As we move forward and others inevitably expand on this novel finding – and the link between a person's unique genetic code and their facial features is revealed – a wanted person's DNA will suddenly reveal much more than just a simple match on a known criminal database. Amazingly, police officers in 2050 will likely be able to create an accurate facial model from a mere drop of saliva or a single strand of hair. Then, with the help of smart computer systems, they will be able to scour the area with drones and locate their target.

> "In today's research we find the seeds of the era-defining technologies that will come to be"

At the centre of these cross-disciplinary technological marvels, however, will lie brain-computer interfaces similar to the kind being developed by Elon Musk's Neuralink. This intriguing company endeavours to create a neural mesh capable of directly linking to the cloud, forming a bridge between our thoughts and the electronic world around us. Musk rightly points to our current reliance on smartphones – and namely how we loathe to be without them – as evidence that we're already bound to technology. But in 2050 this connection will have deepened to the extent that we will have access to implants that form a neural interface around the outside of our brains.

For those equipped with such technology, information from the web will be directly delivered to their thoughts on a moment's notice (much to the chagrin of pub quiz runners); electronic devices will be controlled just by thought; and people will be able to enjoy 'consensual

Tomorrow's cities will be home to vertical farms, enhanced greenery and a multitude of new buildings

Brain-computer interfaces will allow us to control tomorrow's technology by thought alone

Delivery services, provided by autonomous drones, will be faster and cheaper than today's options telepathy'. This may seem the product of sorcery, but in 2050, when technology will be even more integral and abundant than it is today, interfaces that permit easier interactions with our creations will become hugely advantageous. The medical applications of this technology are also worthy of mention, as those with brain and other central nervous system injuries will be able to utilise this tech to circumvent severed connections via the cloud. As a result, communications between the brain and limb will be restored, and those who are severely paralysed will be able to more easily interact with the outside world.

The places we inhabit will also have transformed by 2050. For those who live in rural areas, more land will become available for biodiversity to prosper in once more as agricultural land will be stripped back. With a swelling population we may expect farming land demand to grow rather than dwindle, but many meats will be available in the form of lab-grown varieties, and cities will employ vertical farming to generate food supplies.

Vertical farming, where tiers of crops are stacked atop one another, may take up residence as great glass skyscrapers in tomorrow's cities. There, they will be able to grow nutritious crops including tomatoes, lettuces and greens, as well providing greenery to the urban landscape.

Off-world mining

Many nations throughout the world are committed to cutting down their carbon footprint in the coming decades, with the hope that by 2050 it will be significantly reduced. A vital part of this vision includes an increased reliance on batteries and other electronics, which will be key for renewable energies and emission-free electric cars. But mining enough precious metals to meet the ever-growing demand represents a serious hurdle. One undesirable answer to this problem is to employ deep-sea mining that targets hydrothermal vents. These are known to be rich in metal deposits but are truly remarkable oases of life (and may even be where life began), so a better alternative is needed. This will come in the form of off-world mining on local asteroids as well as our closest companion – the Moon. Mining the Moon holds great promise thanks to its deposits of helium-3, an isotope ejected from the Sun that will eventually be used as fuel in nuclear fusion reactors.

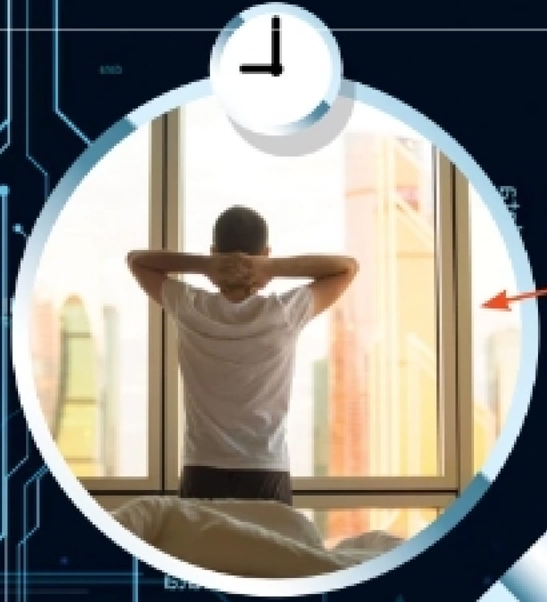
With robot workers and giant 3D printers to create infrastructure, off-world mining will be able to provide us with a continuous supply of precious and much-needed resources.

> "Most meat will be lab grown rather than traditionally farmed"

Mining precious metals off-world will be integral for the future production of electronics

YOUR FUTURE LIFE

Fill the shoes of tomorrow's citizen and uncover what an average day will be like in 2050



9:00am
Most labour and administrative jobs will be completed autonomously, which means many members of the adult population will receive Universal Income and enjoy complete freedom of their time.

9:30am
Advancements in AI and quantum computing will allow us to create truly powerful artificial brains, which will, in part, act as intelligent virtual assistants.

10:00am
Battery-powered, self-driving cars will be readily available as an affordable, safe and eco-friendly taxi service whenever we need it.

11:45am
Increased global trade will lead to a cryptocurrency taking the lead as a universal digital currency to pay for whatever, wherever we are.

12:00pm
Travelling to meetings will be unnecessary thanks to high-definition augmented reality headsets, which will enable interaction in 3D space.

14:30pm
Thanks to Universal Income there will be ample opportunity to book a holiday. Upgrade your ticket to a hypersonic flight and you'll be able to reach anywhere on Earth in just a few hours.

15:00pm
Adverts will interact with our augmented reality headsets to create 3D holograms featuring carefully selected products.

17:00pm
Hyperloop vehicles, housed in cylindrical tunnels underground and above our heads, will travel at nearly 1,000kph to get us home.

17:30pm
Virtual reality headsets, haptic-feedback suits and blistering connection speeds will mean we'll be able to game inside immersive and expansive digital worlds.

19:30pm
To help reduce harmful emissions and intensive farming, most meat will be lab grown rather than traditionally farmed. This will vastly reduce waste as well as the need for large areas of pasture.

© Getty; Shutterstock

Smaller-scale vertical farms may also be affixed to the sides of older buildings, providing cleaner air and extra food sources. It has been estimated that the largest vertical farm structures could provide food for up to 50,000 people. Food loss from transport and storage will be eradicated, fewer pesticides would be needed thanks to the segregated environments, and crops could be grown throughout the year. And, as an added bonus, sealed vertical farms would naturally recycle their own water supply, making the process even more economical.

As a whole, we will find 2050's megacities considerably better equipped and more self-sufficient than those of today. Bioengineered microorganisms will help to clean the water supply, lowering the energy expenditure required for water processing, and we may even save power in the evenings as street lights are replaced by glowing trees.

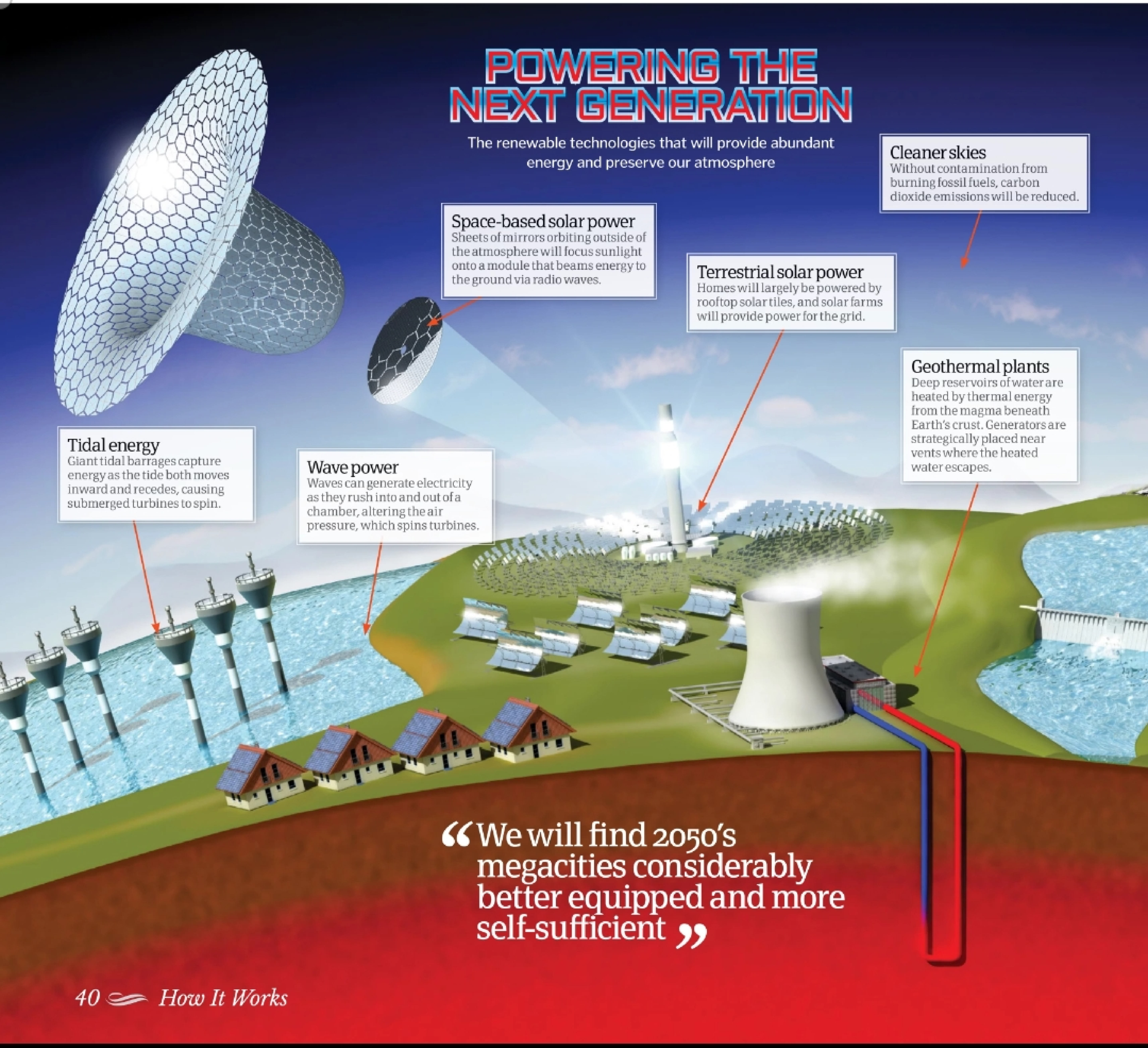
These will be products of technologies that will build upon the success of MIT scientists, who at the end of 2017 successfully engineered leaves using nanoparticles that glowed vibrantly under the plant's own power. Providing both light and beauty to the city, the glowing trees will help transform our metropolises from concrete jungles into otherworldly visual spectacles.

THE RISE OF AUTOMATION

Some of the ideas we have visited thus far in this feature have been likely, some a little more speculative and others wishful, but one thing that companies the world over are barrelling toward is autonomous systems. A world dominated by self-acting machines seems to be etched into our destiny, as every year we uncover greater possibilities and achieve new milestones, some of which have come a decade before their predicted time. Fortunately, this won't lead to an ominous revolution of robots and their artificial intelligences, but rather an integration of autonomous systems into nearly every facet of

POWERING THE NEXT GENERATION

The renewable technologies that will provide abundant energy and preserve our atmosphere



Cleaner skies
Without contamination from burning fossil fuels, carbon dioxide emissions will be reduced.

Space-based solar power
Sheets of mirrors orbiting outside of the atmosphere will focus sunlight onto a module that beams energy to the ground via radio waves.

Terrestrial solar power
Homes will largely be powered by rooftop solar tiles, and solar farms will provide power for the grid.

Geothermal plants
Deep reservoirs of water are heated by thermal energy from the magma beneath Earth's crust. Generators are strategically placed near vents where the heated water escapes.

Tidal energy
Giant tidal barrages capture energy as the tide both moves inward and recedes, causing submerged turbines to spin.

Wave power
Waves can generate electricity as they rush into and out of a chamber, altering the air pressure, which spins turbines.

> "We will find 2050's megacities considerably better equipped and more self-sufficient"

It is hoped that self-driving cars will dramatically reduce road accidents

It is estimated that robots will replace around 800 million workers by 2030

ECO-FRIENDLY IN 2050

Welcome to a future built on renewable and sustainable energy sources

139

The number of countries that could be powered entirely by renewable energies in 2050

24 million

The net gain of jobs created for countries relying solely on renewable energy

2040

The year the UK plans to ban sales of vehicles powered by fossil fuels

42.5%

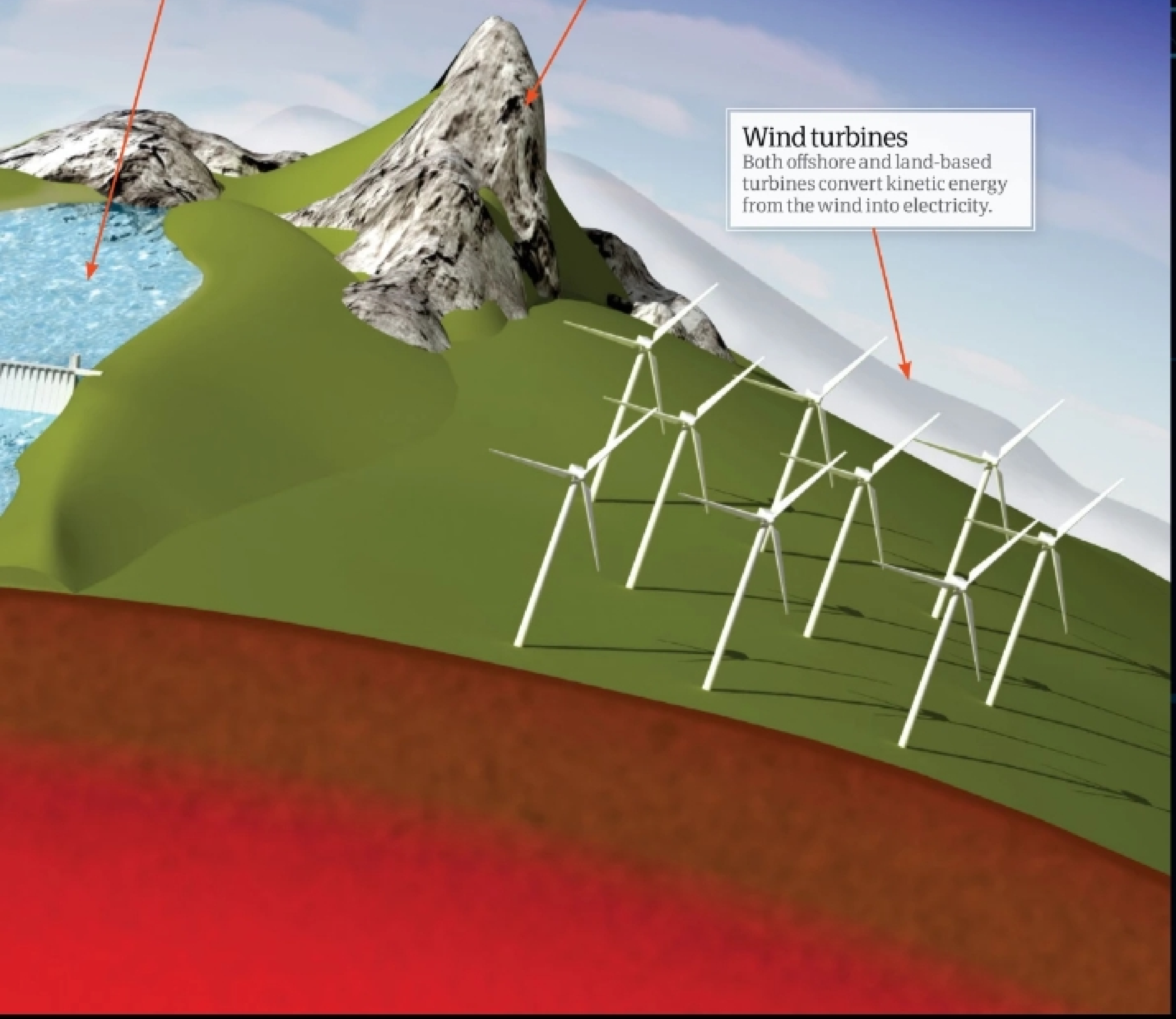
The estimated decrease in energy demand after we switch to efficient renewables

1.1 million tons

The estimated mass of helium-3 on the Moon's surface

48%

The predicted contribution of solar-power-based technologies to energy production in 2050



Hydroelectric energy

Dams can serve a dual purpose of preventing flooding but also providing energy. As water flows through the intake it spins turbines to power generators.

Harnessing nature's energy

Every moment, radiation is ejected from the Sun, our planet spins and its molten core swirls. All of these phenomena release energy, which these technologies will capture.

Wind turbines

Both offshore and land-based turbines convert kinetic energy from the wind into electricity.

our lives. They will become the tireless worker drones that gather, process and organise our data, clean our offices, deliver our parcels and so much more. If we look around us today we can see that this change has already begun. Stock brokers rely on algorithms to predict fluctuations in the stock market; Facebook programs dig through our internet cookies to learn the right advertisements to feed us; and fast food chains are replacing staff with burger-flipping robots.

There are a slew of reasons for this major cultural shift. Algorithms and robots will prove cheaper for companies, more efficient, and when handling data, simply far superior than any human counterpart. The only major hurdle left to overcome in the following years involves teaching machines how to perform a job optimally. But once they've learnt it, you can be certain that they'll be much more capable than their human predecessors.

So what does this mean for jobs? For some, it'll mean a much easier working life. Such beneficiaries will of course include most large business owners, but disciplines such as medicine - and the patients that they treat - will be bolstered by artificially intelligent support. A multitude of disease diagnoses, for instance, are still assessed by eye alone.

This outdated approach has an element of subjectivity and is prone to error, but machines that have been trained on tens of thousands of images will be able to aid medical practitioners by accurately diagnosing diseased tissue.

Yet for many others careers, machinated workers will simply offer a favourable alternative to human employees. One study estimated that certain sectors could see up to 50 per cent of jobs being handed over to robots and AI by 2030, and we can be certain that the following two decades will see machines grow exponentially more capable, and many other careers will come under threat. Jobs that require empathy and creativity are currently believed to be immune to the incoming influx of automation, but can we be so confident that a machine won't be able to outperform a human in these areas by 2050?

Those vying for the remaining jobs, which will likely include policing, governing, teaching, researching and counselling, will face a fiercely competitive environment, especially as the global population is set to increase to nearly 10 billion by 2050. As a result, we may find ourselves in the era of Universal Income, where the governments of the world will provide pay to adults without them having to work. This way the economy keeps turning and the population becomes able to invest their time in whatever they please, free from the pressure of generating income. It would represent the greatest change in our daily lives for hundreds of years and pave the way for people to continue the phenomenal technological upward trend of the past 50 years.

Tunnels kept at near-vacuum pressures will house superfast vehicles known as hyperloops, which will transport future citizens around at 1000kph

Extended lifespans

An ageing population can be a fearful prospect for future generations due to the economic pressures of having to provide and care for a considerable portion of a country's citizens. But what if old didn't have to mean infirm; what if we could prevent the effects of ageing and keep people fitter and healthier for longer? A reality such as this one should be in effect by 2050 with the help of revolutionary regenerative technologies such as telomere extension.

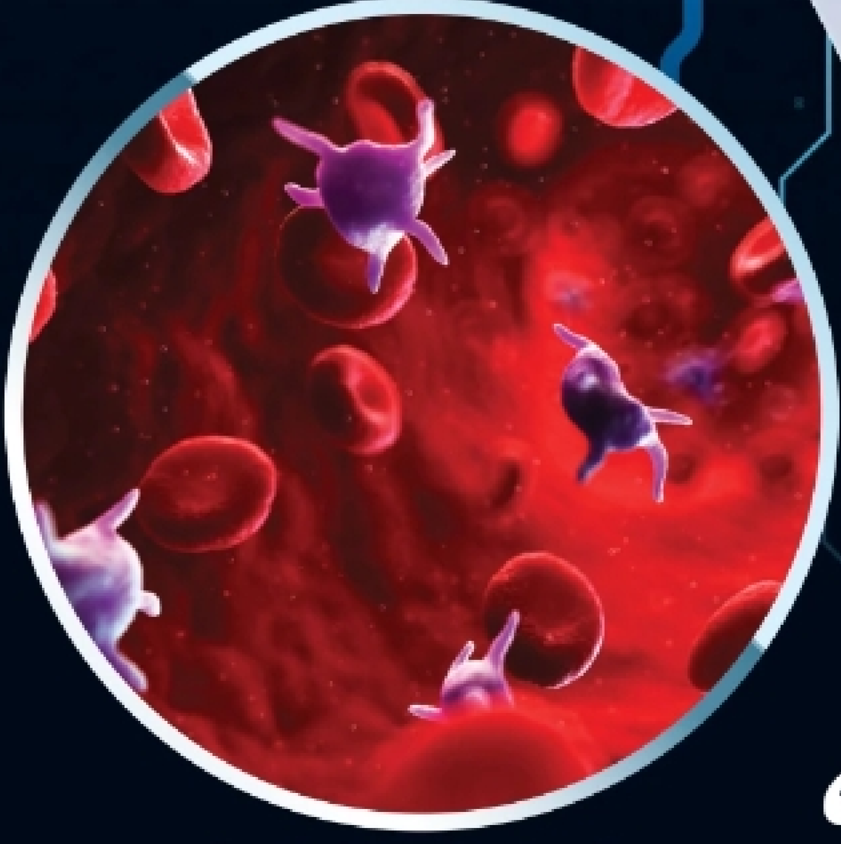
Telomeres are essentially the 'caps' on the ends of our chromosomes, made up of long strings of basic genetic building blocks that are slightly shortened every time a cell divides. When the telomere is gone the cell can no longer properly replicate, and instead it dies. In a way, telomeres represent our natural lifespans, and with recent progress researchers have shown that extending telomeres with the help of proteins can restore cell division and prolong life. So for someone born in 2050, age-related issues including hair loss, compromised bone marrow and heightened cancer susceptibility will be a problem from another century.

TOMORROW'S MEDICAL MILESTONES

Discover the top innovations that will transform the future of healthcare

Monitoring your health 24/7

Through wearable gadgets and small implants, key health indicators such as blood pressure, heart rate, cholesterol levels and blood sugar will all be recorded and transmitted continuously, ensuring that help will be at hand as soon as you need it.



Synthetic blood cells

Plastic 'smart particles' that can bolster the immune response by binding to invading cells, and carbon-based 'respirocytes' carrying 100 times more oxygen than red blood cells, means future generations will enjoy near-superhuman levels of defence and fitness.

The AI doctor

After decades of training intelligent algorithms to recognise patterns and symptoms of disease, 2050's 'consultant computers' will be able to reliably and accurately diagnose almost any condition and recommend the best course of treatment.

> "For someone born in 2050, age-related issues will be a problem from another century"

3D printed organs

With basic biological components as the building material, bioprinters will be able to create new organs from the bottom-up. Simpler organs such as skin, and even more complex systems such as livers and lungs, will free patients from relying on donors.

Advanced bionics

The future of exoskeletons and artificial limbs will rely upon improved robotics for increased synthetic limb acuity, as well as brain-bionic interfaces that wirelessly transmit electrical signals from the brain to an attached appendage, meaning it can be moved by thought alone.

© Virgin Hyperloop One; Alamy; Getty

Putting something under lock and key is really all about pattern-matching

How do keys open doors?

Unlock the secrets of how these simple devices keep your possessions safe

Throughout history, numerous lock-and-key combinations have been used to keep rooms and valuables secure. The earliest lock comprised of a series of wooden pins that could be moved only by a key with a matching profile. Called a pin-lock, it formed the basis of today's pin-tumbler lock (often called a Yale or radial lock).

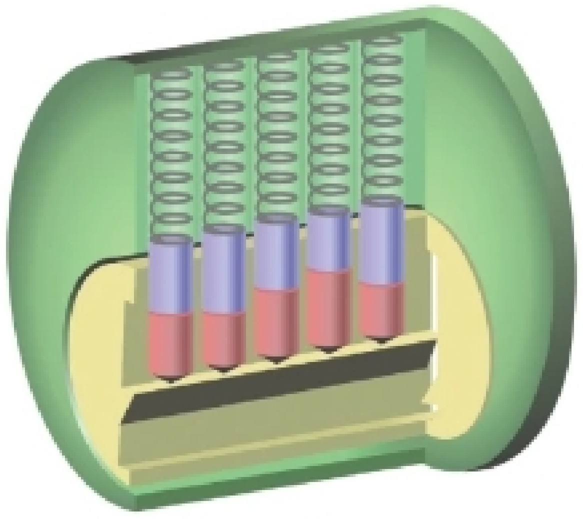
Inside the barrel of a pin-tumbler lock is a series of spring-loaded, two-part pins of varying length. When a small, flat-sided key is inserted into the barrel, the serrations along its edge push the pins up. If the key is the correct one for the lock, the pins will line up so that the bottom half of the pins sit perfectly inside the barrel. This enables the barrel to be turned (or tumbled) with the key, which opens the lock. Other keys may fit into the lock, but the lack of pin-alignment stops the barrel from turning.

Not all keys are flat, though. Those that fit into warded locks – used widely during the Middle Ages – are cylindrical. Instead of pins, these locks use curved plates, or wards, to block incorrect keys from turning. Only those with matching 'notches' can rotate fully. This design led to the first skeleton keys – versions that had most of their notches filed down to avoid the wards.

Many companies are now developing mechanical door locks that don't need physical keys. They can be opened with the sound of your voice or a swipe of your smartphone – although most still allow you to use an old-fashioned key.

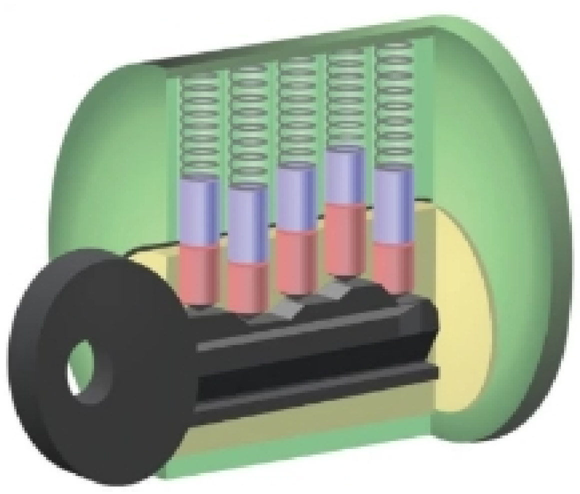
How keys work

Take a look inside a pin-tumbler lock to understand how keys open doors



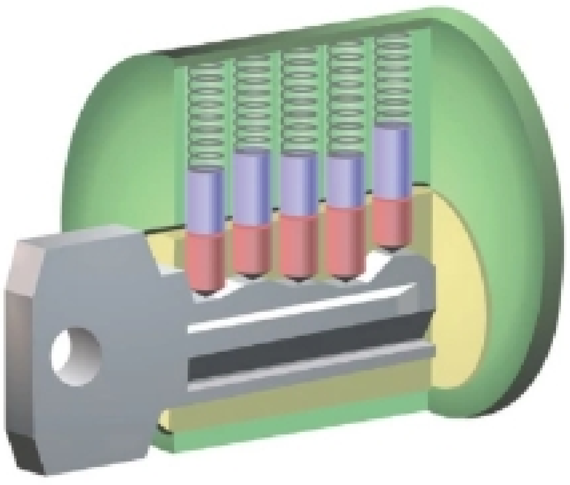
1 Springs and pins

A series of spring-loaded pins sit inside every cylindrical lock barrel. While the total length of each pin remains the same, the length of the separate sections of the pin (shown in purple and red) varies.



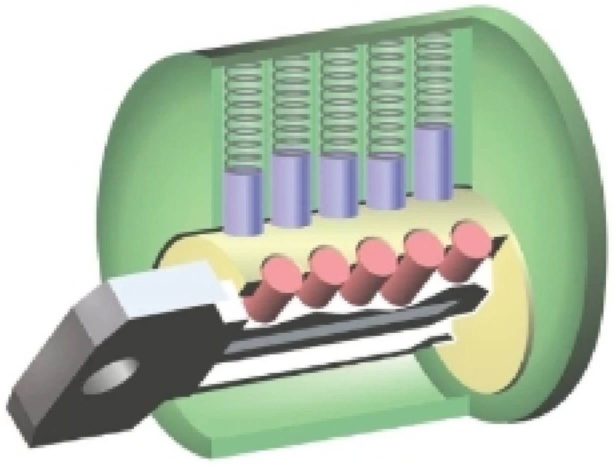
2 If it doesn't fit...

When a flat-sided key is inserted into a lock, its bumpy edge pushes the pins to different heights. When it's the wrong key, there is no alignment between the red sections of the pins.



3 Line them up

When the correct key is inserted into the lock, it pushes the pins up so that the break in the pins (where the red and purple sections meet) aligns exactly with the top of the gold-coloured barrel.



4 Open sesame!

Because the pins are in two parts, this alignment means that only the red sections sit within the barrel, which enables the barrel to turn, or tumble, opening the lock in the process.

The end of lost keys?

A British insurance company estimated that the average person spends 3,680 hours – that's 153 days – searching for misplaced items, mainly smartphones and keys. However, a gadget called Tile can dramatically reduce these wasted hours, helping you find your essential items quickly and easily. Each Tile contains a Bluetooth tracking device. If you attach it to your valuables, it can transmit its location – in the form of radio waves – over short distances, using very little power.

Almost all current smartphones have in-built Bluetooth, so by installing a dedicated app, they can wirelessly communicate with your Tiles. If you lose your keys, the app then directs you to their location using sound. If you misplace your phone, you can ring it by pushing a button on one of your Tiles. A great feature is that it plays a tune even if it's on silent!

Tile tags act like homing beacons to help you track down missing valuables

© Thinkstock, Crisco

How do food blenders work?

Turn fruit salad into smoothie with a tornado in a jar

A smoothie blender is a compact fluid dynamics laboratory. Friction at the surface of the blades accelerates the liquid, centrifugal force pushes it outwards, atmospheric pressure creates an air-filled vortex in the centre, and turbulence keeps everything churning and mixing. Within seconds, your placid pint of milk and fruit chunks is transformed into a chaotic, churning maelstrom.

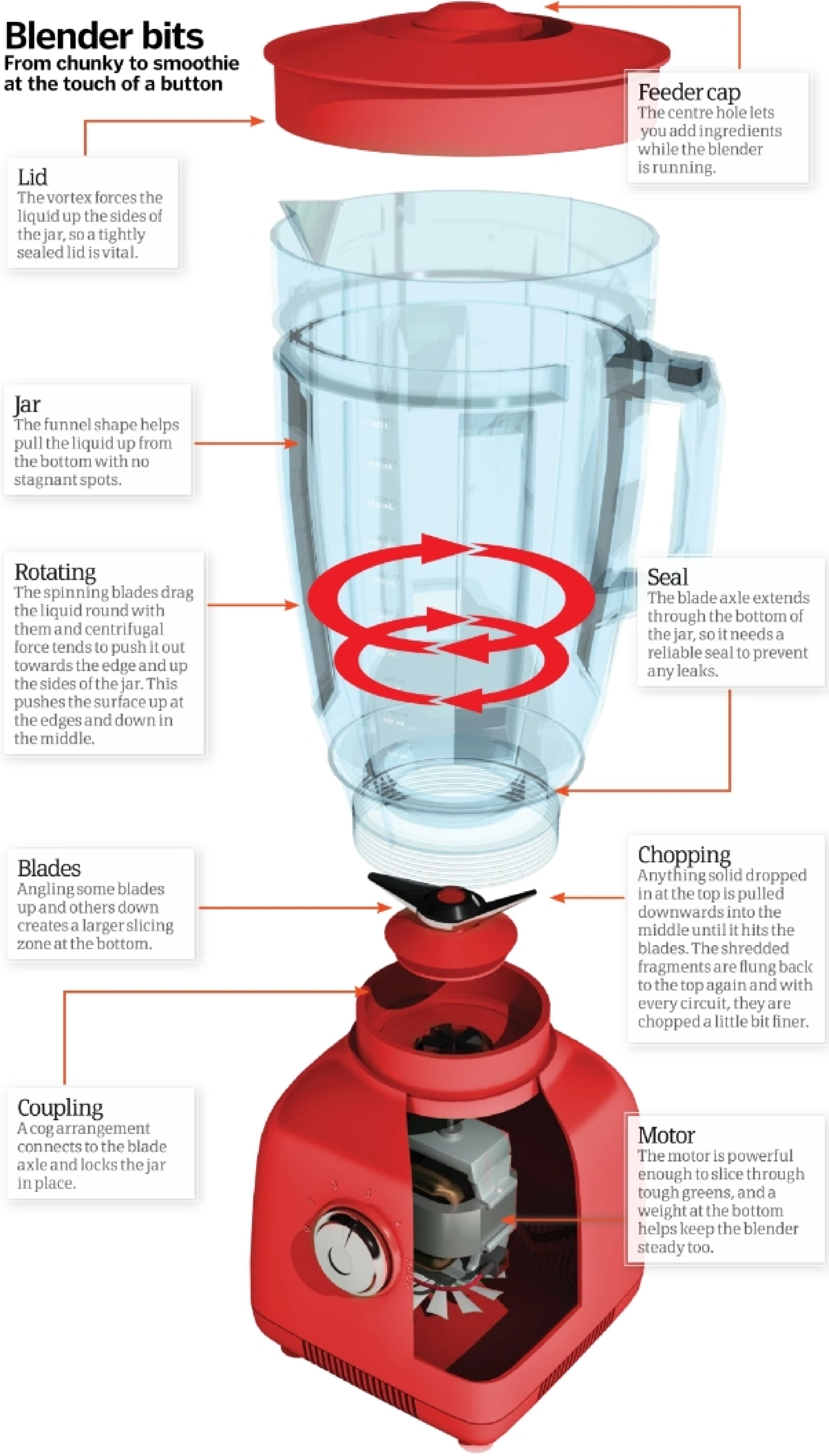
The vortex in the centre of a blender looks like a tornado but it acts in quite a different way. A tornado is powered by a thermal updraft in its centre that pulls everything into the middle and flings it up to the sky. In a blender, the spinning blades at the bottom are constantly pushing the liquid away from the middle to the edges of the jar and this creates a suction that pulls material downwards in the centre.

The cutting blades do most of the initial work of chopping up the solid chunks, but once the size of the pieces drops below a certain point, the blades can't hit hard enough to slice them up any smaller. Amazingly, the blender uses implosion shock waves to finish the job. The blades are spinning so fast that they create a vacuum on their trailing edge. The water caught in their wake effectively boils, and as the tiny steam bubbles condense and collapse again, they send out a cascade of shock waves that shatter the food particles even further.

Don't forget to put the lid on!

Blender bits

From chunky to smoothie at the touch of a button



Feeder cap
The centre hole lets you add ingredients while the blender is running.

Lid
The vortex forces the liquid up the sides of the jar, so a tightly sealed lid is vital.

Jar
The funnel shape helps pull the liquid up from the bottom with no stagnant spots.

Rotating
The spinning blades drag the liquid round with them and centrifugal force tends to push it out towards the edge and up the sides of the jar. This pushes the surface up at the edges and down in the middle.

Seal
The blade axle extends through the bottom of the jar, so it needs a reliable seal to prevent any leaks.

Blades
Angling some blades up and others down creates a larger slicing zone at the bottom.

Chopping
Anything solid dropped in at the top is pulled downwards into the middle until it hits the blades. The shredded fragments are flung back to the top again and with every circuit, they are chopped a little bit finer.

Coupling
A cog arrangement connects to the blade axle and locks the jar in place.

Motor
The motor is powerful enough to slice through tough greens, and a weight at the bottom helps keep the blender steady too.

© Thinkstock; Illustration by Adrian Mann

How do we turn waste into energy?

They say one man's trash is another man's treasure – that's exactly the case when it comes to waste energy

In 2014, the UK generated 209 million tons of rubbish. Of that, 44.9 per cent was recovered (including recycling and energy recovery) and 23.1 per cent was sent to landfill. We are constantly searching for a more efficient and beneficial way to dispose of our waste.

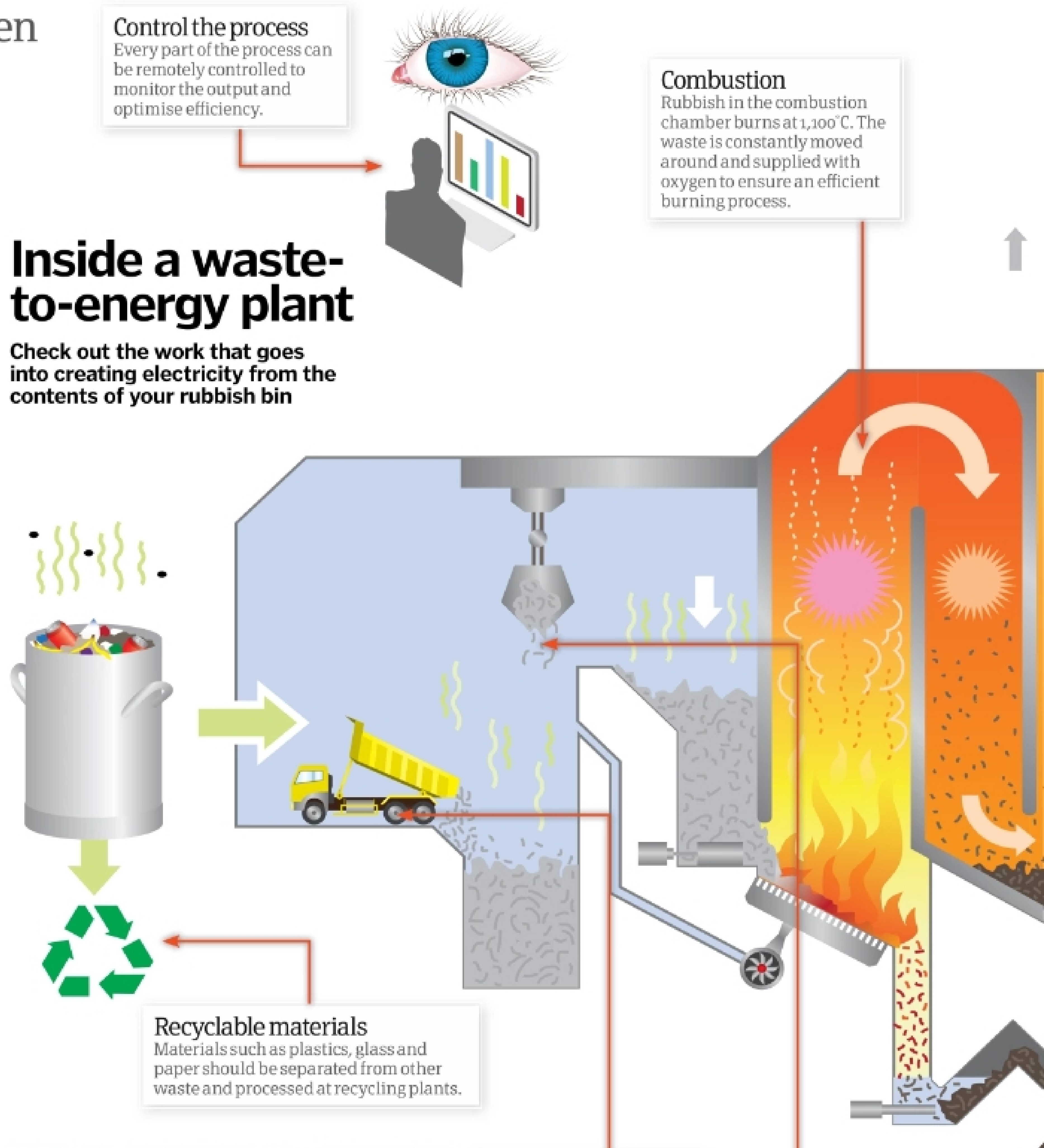
As well as diligently recycling our rubbish, waste-to-energy plants provide one alternative to landfill: the waste is disposed of and used to provide energy to produce fuel and electricity. There are a few different ways that this can be done using thermal energy and biological processes. Thermal processes involve methods like gasification, thermal depolymerisation and pyrolysis; all rather complex procedures that essentially use the application of high temperatures to break down the waste and release energy. The non-thermal waste-to-energy processes use microorganisms to decompose organic matter and release biogas. These processes often take much longer but are considered much more eco-friendly.

The advantages of waste-to-energy technology are that less waste gets sent to landfill. This means less methane – a damaging greenhouse gas – is produced from decomposing rubbish and less leachate (which pollutes groundwater) leaks from the site. Another advantage is that more energy can be created without burning fossil fuels and releasing greenhouse gases. However, despite the advantages, there are also some serious environmental concerns.

The burning of so much mixed waste can release harmful chemicals, such as dioxins and furans (carcinogens released by burning plastics such as PVC) as well as heavy metals, acidic gases, sulphur and nitrogen oxides and particulate matter. Although there are many pollution control processes in effect, not enough is yet known about the extent of the chemicals released and their impact on the environment and human health.

Inside a waste-to-energy plant

Check out the work that goes into creating electricity from the contents of your rubbish bin



Control the process
Every part of the process can be remotely controlled to monitor the output and optimise efficiency.

Combustion
Rubbish in the combustion chamber burns at 1,100°C. The waste is constantly moved around and supplied with oxygen to ensure an efficient burning process.

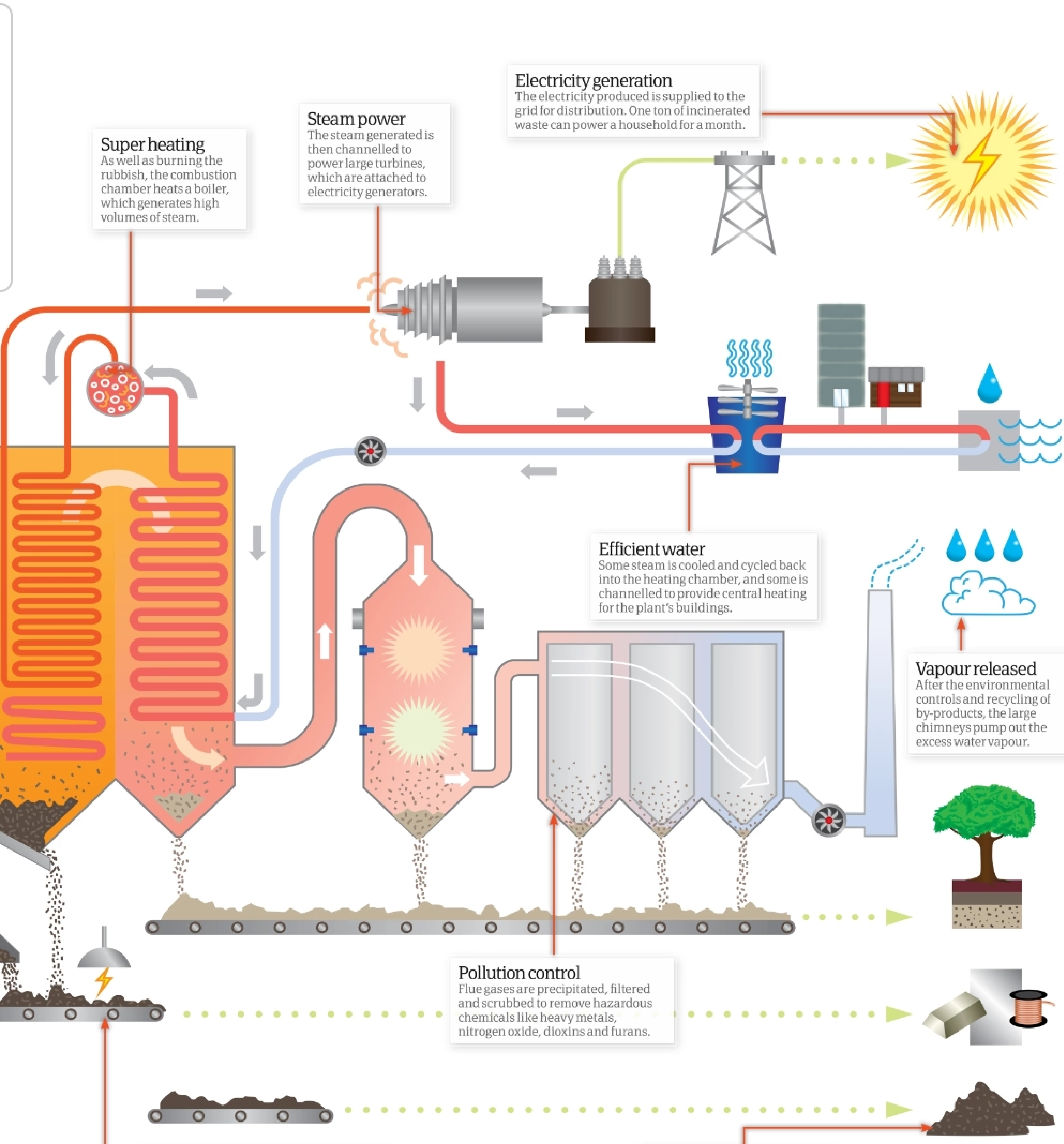
Recyclable materials
Materials such as plastics, glass and paper should be separated from other waste and processed at recycling plants.

Rubbish collection
Waste is collected from homes and deposited at the waste-to-energy plant.

Waste materials
The rubbish is mixed thoroughly before being transported and added into the incinerator.

Landfill sites are lined and sealed to hold rubbish and then buried when the site is full

The Colnbrook Incinerator is one of the largest in the UK, capable of recovering energy from 410,000 tons of waste per year



Electricity generation
The electricity produced is supplied to the grid for distribution. One ton of incinerated waste can power a household for a month.

Steam power
The steam generated is then channelled to power large turbines, which are attached to electricity generators.

Super heating
As well as burning the rubbish, the combustion chamber heats a boiler, which generates high volumes of steam.

Efficient water
Some steam is cooled and cycled back into the heating chamber, and some is channelled to provide central heating for the plant's buildings.

Vapour released
After the environmental controls and recycling of by-products, the large chimneys pump out the excess water vapour.

Pollution control
Flue gases are precipitated, filtered and scrubbed to remove hazardous chemicals like heavy metals, nitrogen oxide, dioxins and furans.

Ash products
The bottom ash goes through a magnet to remove metals for recycling. Fly ash is captured, filtered and then sent to landfill.

By-product uses
The larger particles of unburned waste (called bottom ash) can be used as aggregate for building roads and railways.

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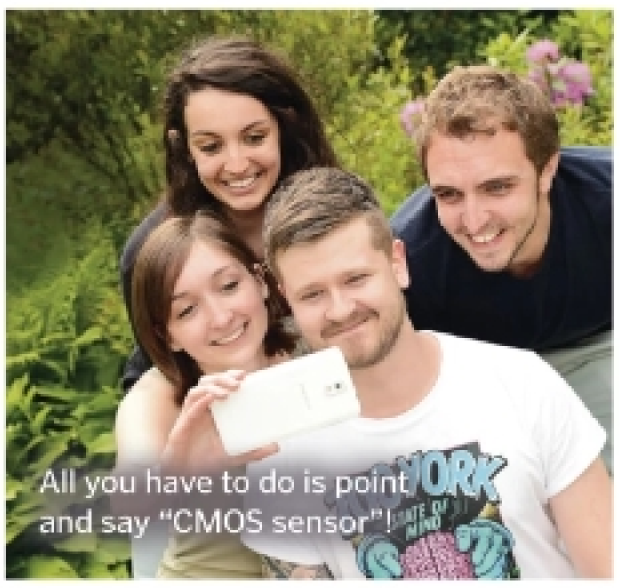
How are digital images captured?

How a camera converts light into photo files on a memory card



All you have to do is point and say "CMOS sensor"!

With the simple click of a button, a digital camera turns light into data. This process starts with the image sensor, which is a silicon chip known as a CCD or CMOS. When light enters the camera lens, it is focused onto the sensor and dislodges some of the electrons in a tiny area of the silicon (known as a pixel), which creates an electrical charge. The brighter the light in that part of the image, the stronger the electrical charge that is created at that spot on the sensor.

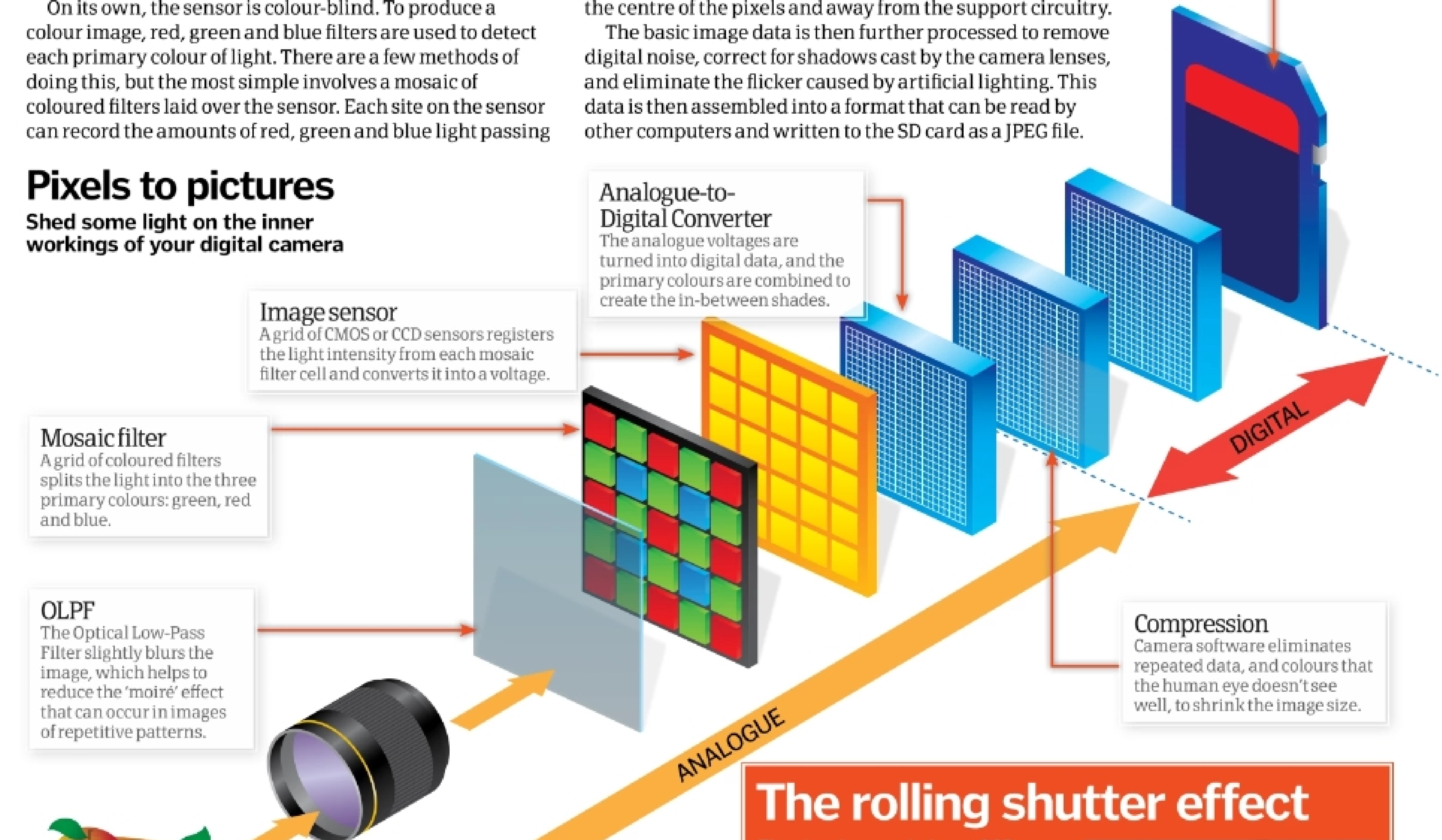
On its own, the sensor is colour-blind. To produce a colour image, red, green and blue filters are used to detect each primary colour of light. There are a few methods of doing this, but the most simple involves a mosaic of coloured filters laid over the sensor. Each site on the sensor can record the amounts of red, green and blue light passing through a set of four pixels on the mosaic. The colour intensity at each pixel is averaged with the neighbouring pixels to recreate the true colours of the image using special algorithms that run through the camera's Central Processing Unit (CPU).

Each pixel needs some circuitry around it to allow electrical charges to be amplified and read. The light that falls on this part of the sensor chip is lost, so some cameras use a grid of microscopic lenses that funnel more light to the centre of the pixels and away from the support circuitry.

The basic image data is then further processed to remove digital noise, correct for shadows cast by the camera lenses, and eliminate the flicker caused by artificial lighting. This data is then assembled into a format that can be read by other computers and written to the SD card as a JPEG file.

Pixels to pictures

Shed some light on the inner workings of your digital camera



Storage
Files are initially stored in fast RAM, and then written out to the permanent flash RAM storage on the SD card.

Analogue-to-Digital Converter
The analogue voltages are turned into digital data, and the primary colours are combined to create the in-between shades.

Image sensor
A grid of CMOS or CCD sensors registers the light intensity from each mosaic filter cell and converts it into a voltage.

Mosaic filter
A grid of coloured filters splits the light into the three primary colours: green, red and blue.

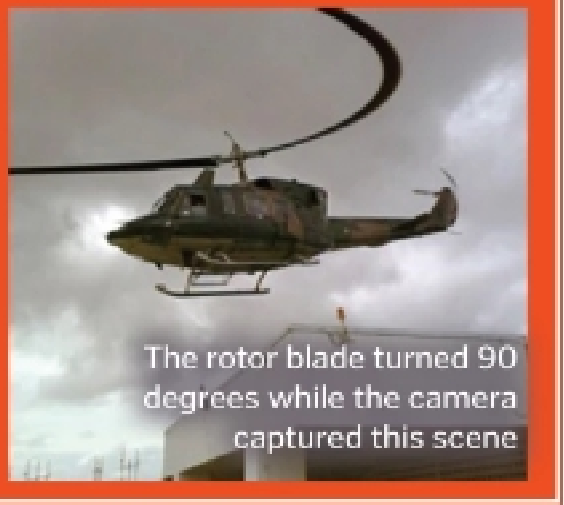
OLPF
The Optical Low-Pass Filter slightly blurs the image, which helps to reduce the 'moiré' effect that can occur in images of repetitive patterns.

Compression
Camera software eliminates repeated data, and colours that the human eye doesn't see well, to shrink the image size.

Subject
Light bounces off the photo subject and enters the camera lens, where it is focused into an image.

The rolling shutter effect

The signals recorded on a CCD sensor are sent one row at a time to the Analogue-to-Digital Converter. This row-by-row recording of the image is known as a 'rolling shutter', and although it happens very quickly, a fast-moving image might still have changed in the time it takes to scan from the top to the bottom of the sensor. This is why propellers and helicopter rotor blades often look strangely bent in digital photos.



The rotor blade turned 90 degrees while the camera captured this scene

How do wristwatches tick?

Keep time with the springs and gears of a mechanical watch

Before you could check your smartphone, and even before quartz batteries, a personal timepiece was a valuable commodity. There are two types of mechanical watch: a hand-wound watch and an automatic or self-winding watch. Although the starting mechanisms are different, the movement inside is essentially the same. It all comes from the back and forth motion of the mainspring – this is a tightly coiled and precisely measured spring, wound into a perfectly weighted cog known as the balance wheel.

This wheel is able to move back and forth because it's helped by another series of cogs that transfer energy from the winding pin all the way to the balance wheel. This usually involves three cogs, and these correspond to the hour, minute and second hands on the face. When the second hand makes a complete revolution, the minute hand has moved one graduation, and so on.

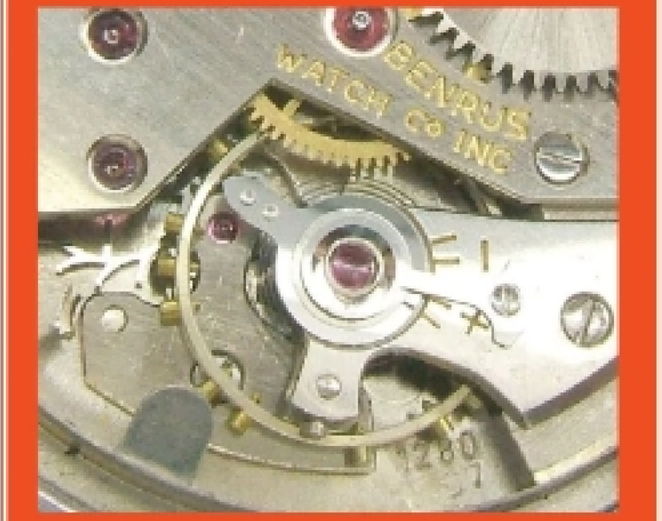
When each of the cogs turns the next, the last one in the chain moves what is known as the escape wheel. This wheel has large teeth on it, shaped so that it jogs a piece called the pallet fork into motion, which then in turn moves the balance wheel. As the balance wheel swings back, the other side of the pallet fork knocks the balance wheel again, and so a back-and-forth swing motion continues, ultimately helping the watch to keep perfect time.

Watch jewels

When you see a watch that has a phrase like '17 jewel' inscribed on the back, this is nothing to do with the watch face. It may be adorned with numerous precious stones on the front, but this inscription refers to the gemstones (usually man-made sapphires or rubies) that are contained within the watch's mechanisms.

These jewels are not precious gemstones and have no monetary value, but they are incredibly important for keeping the watch ticking smoothly, providing highly polished surfaces to decrease friction and improve accuracy.

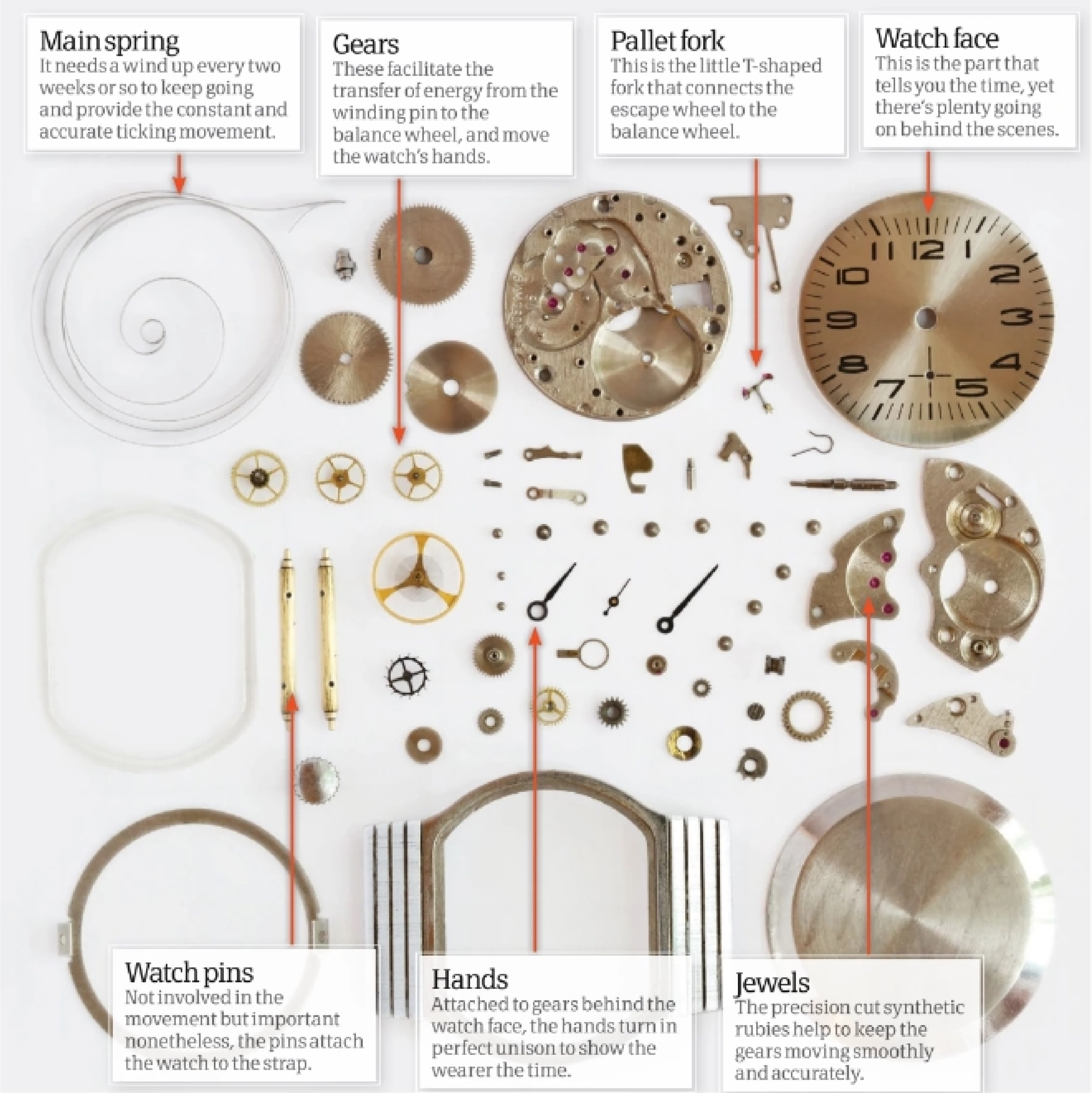
The jewels also increase the life of the watch. They are usually tiny – just millimetres in diameter – and come in different shapes for their specific jobs. There are two pallet jewels on the pallet fork that keep the balance wheel moving back and forth. There are also cap jewels, hole jewels and impulse jewels, among many others.



Here the cap and hole jewels are visible, providing smooth movement for the gears

Telling the time

How individual parts fit together so everything goes like clockwork



Main spring
It needs a wind up every two weeks or so to keep going and provide the constant and accurate ticking movement.

Gears
These facilitate the transfer of energy from the winding pin to the balance wheel, and move the watch's hands.

Pallet fork
This is the little T-shaped fork that connects the escape wheel to the balance wheel.

Watch face
This is the part that tells you the time, yet there's plenty going on behind the scenes.

Watch pins
Not involved in the movement but important nonetheless, the pins attach the watch to the strap.

Hands
Attached to gears behind the watch face, the hands turn in perfect unison to show the wearer the time.

Jewels
The precision cut synthetic rubies help to keep the gears moving smoothly and accurately.

© Dreamstime

How do industrial robots work?

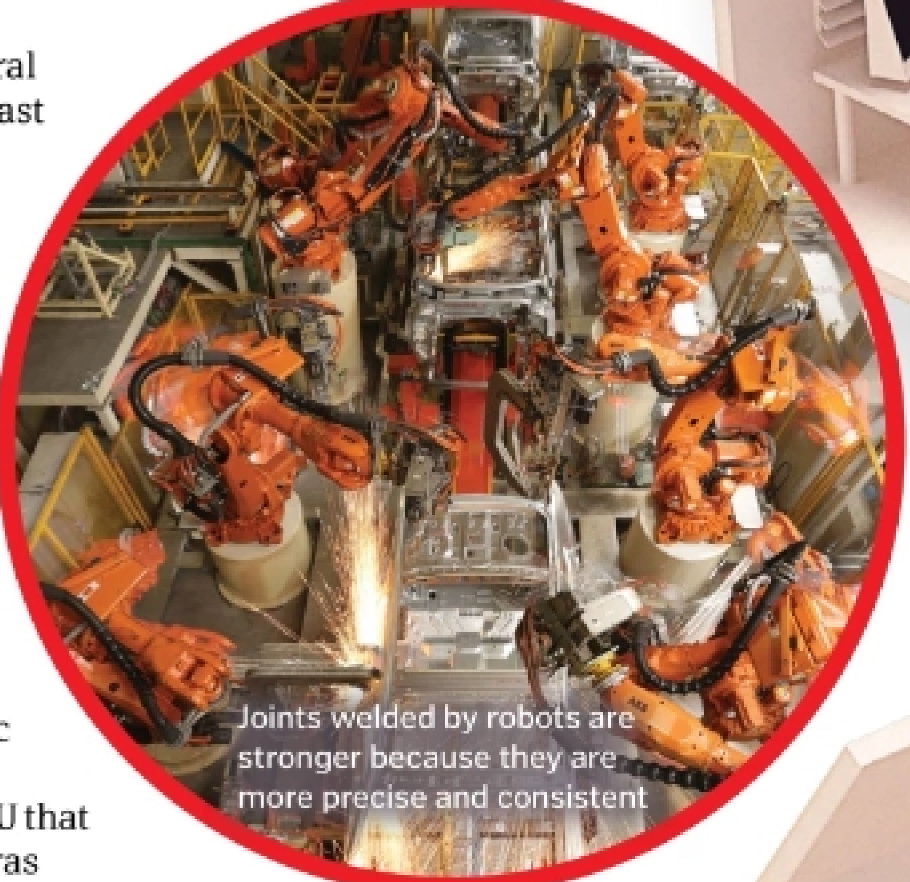
Inside the factories where no one gets tired, sick or even paid

Ninety per cent of all the robots in the world live in factories. The availability of cheap human labour in China and the Far East hasn't slowed down the march of machines, and sales of industrial robots are in fact growing faster in China than anywhere else in the world.

Robots were first put to work in 1961, when General Motors installed Unimate. This was a 1.8-ton, die-cast robot arm that dealt with red-hot, metal car door handles and other parts – dangerous and unpleasant work for humans. Unimate followed instructions stored on a magnetic drum (the forerunner of today's computer hard disks), and could be reprogrammed to do other jobs. When Unimate robots took over the job of welding car bodies in 1969, the GM plant in Ohio was able to build 110 cars an hour – twice as fast as any factory in the world at that time.

Modern industrial robots have evolved from using clumsy hydraulic pistons to much more precise electric motors for each joint. Sensors on each one detect an LED light shining through a disc with slots cut into it. As the slots interrupt the light beam, they send a series of pulses to the robot's CPU that tells it precisely how far the arm has moved. Cameras mounted on the end of each arm use sophisticated image-processing software that allows them to identify objects, even if they are upside down or rotated on the conveyor belt, while ultrasound proximity sensors prevent the robots from striking obstacles in their path.

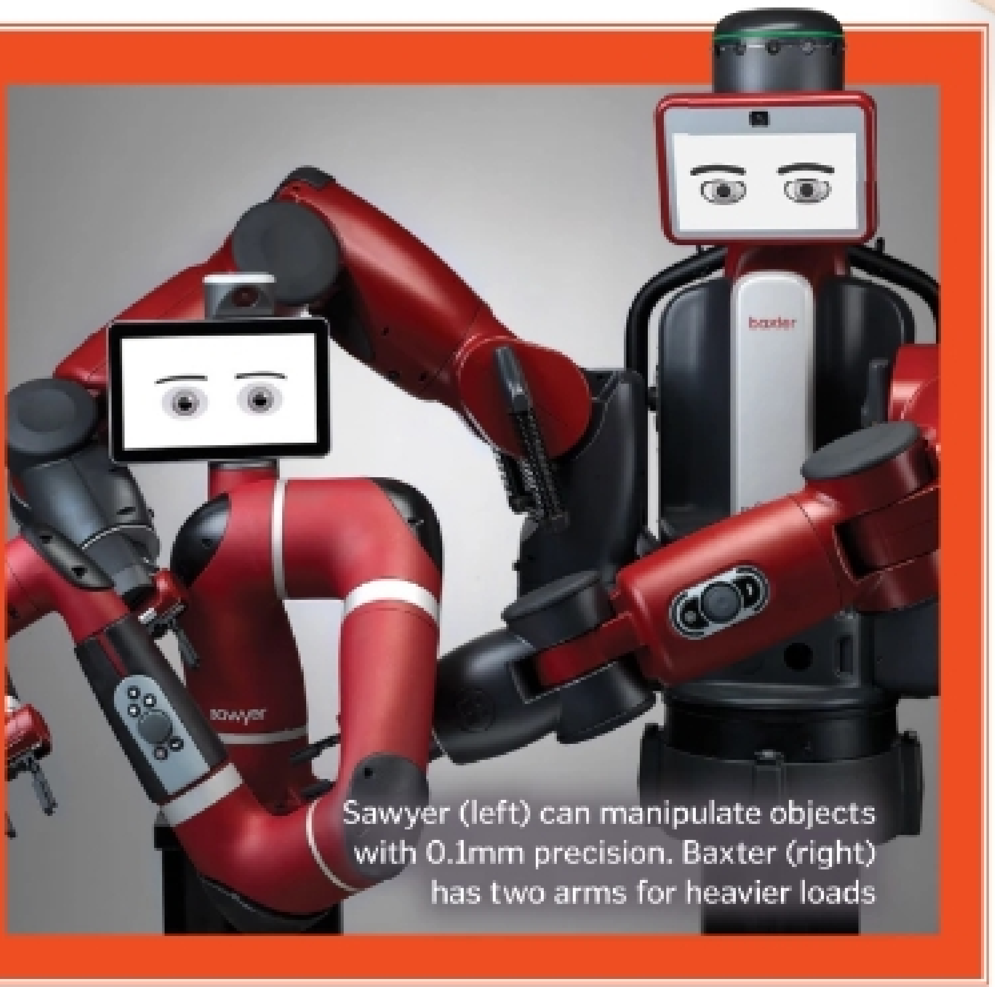
Even with all this sophistication, industrial robots are so strong and move so quickly that it has always been dangerous for humans to share an assembly line with them. But the latest machines have joints driven by springs, which are tensioned by motors, instead of motors driving the arm joints directly. This absorbs the force from an accidental knock, and enables the robot to react in time to avoid an injury.



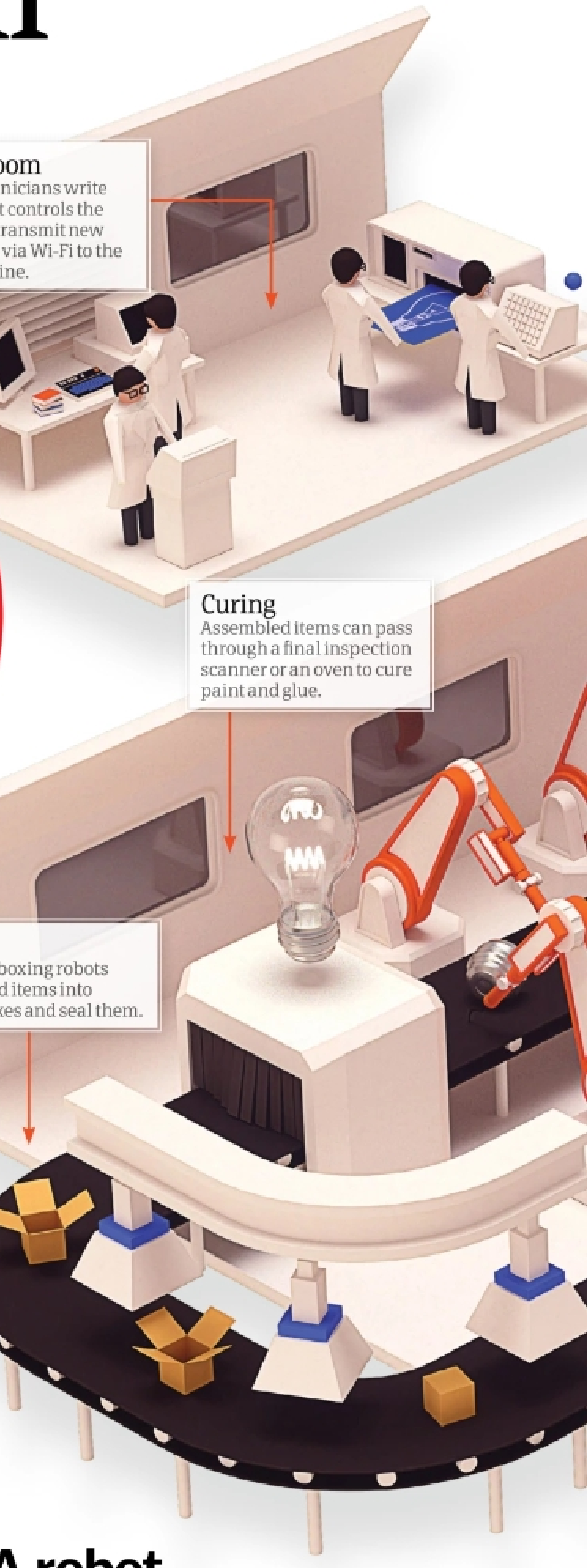
Joints welded by robots are stronger because they are more precise and consistent

Learning by example

Most industrial robots need programmers to write the complex code that controls their movements, and reprogramming them can involve expensive stoppages. Baxter and Sawyer are a new generation of robots from Rethink Robotics in Boston, US. They can be taught what to do by moving their arms to the right position and then clicking a button to tell them 'this is the thing you need to pick up', or 'place the object in this box'. The face on the display screen allows humans to tell whether the robots are concentrating on learning a new task, working happily or have encountered a problem.



Sawyer (left) can manipulate objects with 0.1mm precision. Baxter (right) has two arms for heavier loads



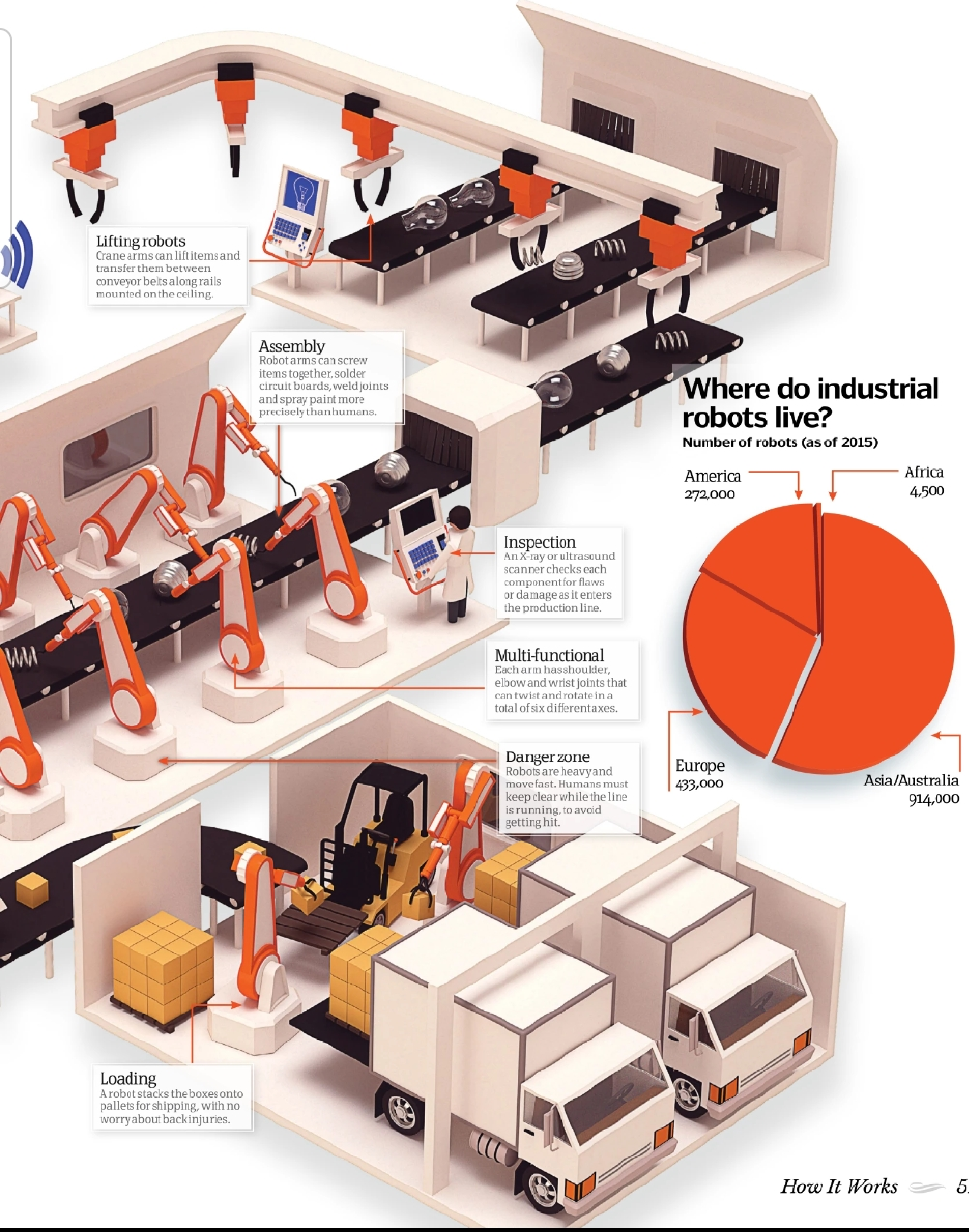
Control room
Human technicians write the code that controls the robots, and transmit new instructions via Wi-Fi to the production line.

Curing
Assembled items can pass through a final inspection scanner or an oven to cure paint and glue.

Boxing
Specialised boxing robots pack finished items into shipping boxes and seal them.

A robot assembly line

Robots handle the most stressful and repetitive jobs, while humans supervise



Lifting robots
Crane arms can lift items and transfer them between conveyor belts along rails mounted on the ceiling.

Assembly
Robot arms can screw items together, solder circuit boards, weld joints and spray paint more precisely than humans.

Inspection
An X-ray or ultrasound scanner checks each component for flaws or damage as it enters the production line.

Multi-functional
Each arm has shoulder, elbow and wrist joints that can twist and rotate in a total of six different axes.

Danger zone
Robots are heavy and move fast. Humans must keep clear while the line is running, to avoid getting hit.

Loading
A robot stacks the boxes onto pallets for shipping, with no worry about back injuries.

Where do industrial robots live?

Number of robots (as of 2015)

© Zen wave, Illustration by Nicholas Forder

How does new tech fight fires?

The cutting-edge tools helping to battle blazes and save lives

Firefighters put their lives at risk every day to rescue people from burning buildings and to stop the spread of raging fires, often with nothing more than a hose and a ladder. But the latest developments in firefighting technology are helping to make the job much easier and safer, speeding up rescue missions and keeping the firefighters out of harm's way.

Enormous, water-carrying aircraft can come to the rescue when widespread and unpredictable wildfires get out of control, and drones and robots can assist fire crews in city blazes, when visibility may be poor and structures are unsafe for humans to enter.

Even the method of dousing the flames is getting an upgrade, as water is being replaced by chemical fire retardants that can ultimately help the re-growth of plants that once grew on the scorched terrain.

In the future, there may be no need for human firefighters at all, as high-tech machines could tackle dangerous infernos completely unaided, using blasts of electric current to essentially snuff out the flames in an instant.

> "The latest developments in firefighting technology are helping to make the job much easier and safer"

Drones
Korean researchers have developed a drone called the Fireproof Aerial Robot System that can fly and climb walls to search for fires in skyscrapers. It is able to withstand temperatures of over 1,000 degrees Celsius for more than one minute, and relays information to firefighters on the ground to aid rescue missions.

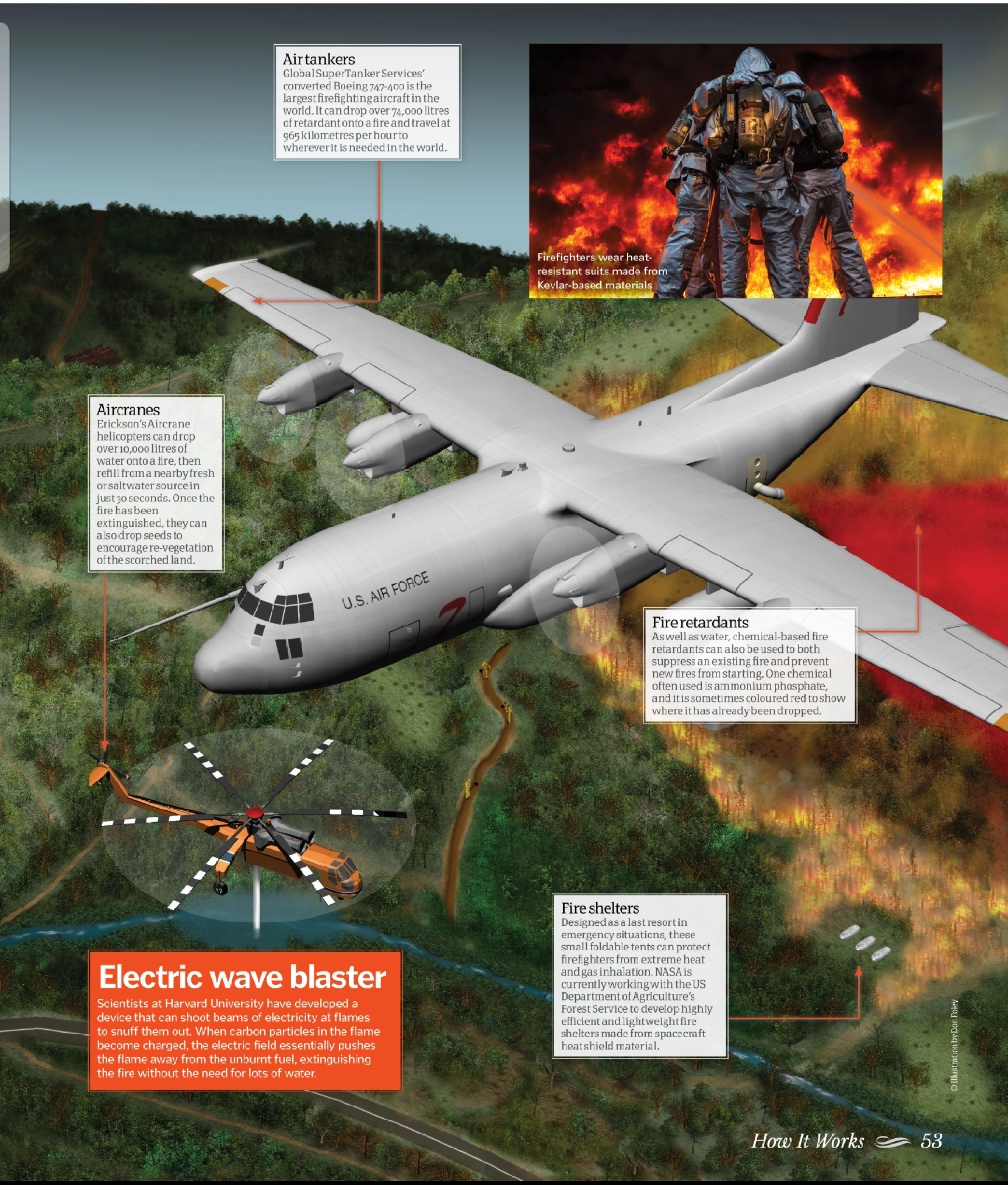
Hydraulic claws
The Heli-Claw drops vast amounts of shredded wood on scorched earth to rehabilitate the area.

Thermal imaging cameras
Thick smoke can sometimes obscure firefighters' view of the scene, so thermal imaging cameras can be used to locate hotspots and those in need of rescue. These cameras can be handheld by the firefighters themselves or mounted on drones or helicopters to relay aerial information to ground crews.

Concrete pounder
The Controlled Impact Rescue Tool, developed by defence contractor Raytheon, fires blank ammunition cartridges to drive an impactor. This sends shockwaves through concrete structures and causes them to crumble. It can breach a concrete wall in less than half the time of traditional methods, helping firefighters reach those trapped inside.

Fire prediction software
Prometheus is a computer program developed by the Canadian Interagency Forest Fire Centre, which uses climate and ecological data to predict wildfires and create simulations showing how they might spread. This information can then be used by firefighting crews to plan their approach.

Robots
London's Fire Brigade trialled a team of firefighting robots that can climb stairs, shoot water and grab things with giant claws. They are designed to help extinguish fires involving acetylene gas cylinders, which can continue to heat up even after a fire has been extinguished.



Firefighters wear heat-resistant suits made from Kevlar-based materials

Air tankers

Global SuperTanker Services' converted Boeing 747-400 is the largest firefighting aircraft in the world. It can drop over 74,000 litres of retardant onto a fire and travel at 965 kilometres per hour to wherever it is needed in the world.

Aircranes

Erickson's Aircrane helicopters can drop over 10,000 litres of water onto a fire, then refill from a nearby fresh or saltwater source in just 30 seconds. Once the fire has been extinguished, they can also drop seeds to encourage re-vegetation of the scorched land.

Fire retardants

As well as water, chemical-based fire retardants can also be used to both suppress an existing fire and prevent new fires from starting. One chemical often used is ammonium phosphate, and it is sometimes coloured red to show where it has already been dropped.

Fire shelters

Designed as a last resort in emergency situations, these small foldable tents can protect firefighters from extreme heat and gas inhalation. NASA is currently working with the US Department of Agriculture's Forest Service to develop highly efficient and lightweight fire shelters made from spacecraft heat shield material.

Electric wave blaster

Scientists at Harvard University have developed a device that can shoot beams of electricity at flames to snuff them out. When carbon particles in the flame become charged, the electric field essentially pushes the flame away from the unburnt fuel, extinguishing the fire without the need for lots of water.

© Illustration by Don Foley

How are medical tablets made?

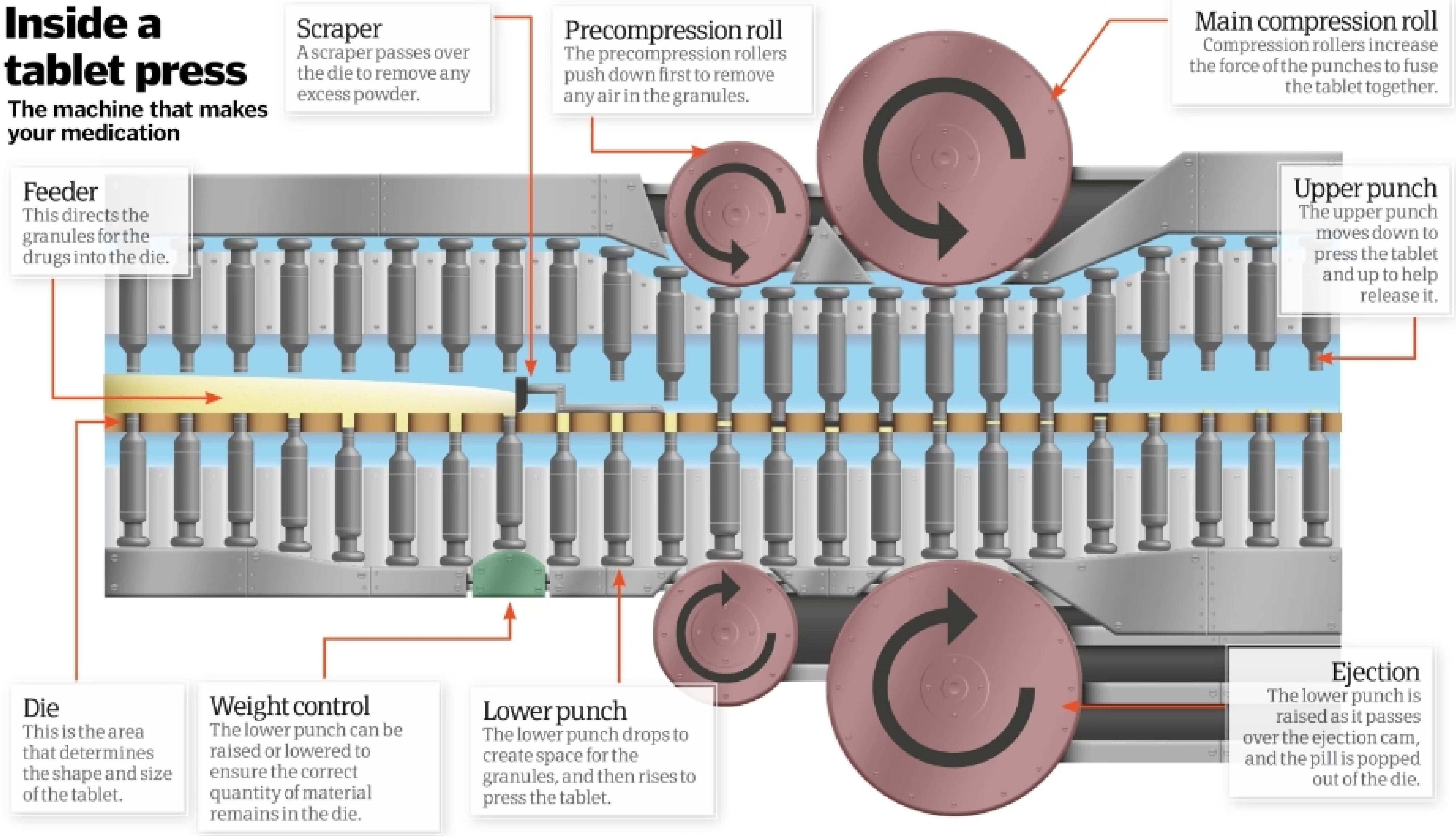
Pharmaceutical companies use machines called tablet presses to transform powders into tablets. To start, the powdered material is fed into a hopper and flows through housing into a die that holds a small amount of powder. The die lies between two punches that will press the powder into shape. The lower punch drops down, allowing the granules to fill the space to the exact measurement needed for the type of tablet.

A scraper then removes any excess powdered material and the upper and lower punches then compress together; first at low pressure to remove any excess air in the powder, then at higher pressure to form the tablet.

The size and shape of the dies and punches are different for each medication so that companies can create unique shapes, as well as stamp their brand name into the pills. Once the tablet is pressed, the upper punch raises and the lower punch ejects the tablet, which goes down a chute to be collected. Each tablet press contains numerous individual stations, allowing for the production of hundreds of thousands of tablets every hour.

Inside a tablet press

The machine that makes your medication



Scraper A scraper passes over the die to remove any excess powder.

Precompression roll The precompression rollers push down first to remove any air in the granules.

Main compression roll Compression rollers increase the force of the punches to fuse the tablet together.

Feeder This directs the granules for the drugs into the die.

Upper punch The upper punch moves down to press the tablet and up to help release it.

Die This is the area that determines the shape and size of the tablet.

Weight control The lower punch can be raised or lowered to ensure the correct quantity of material remains in the die.

Lower punch The lower punch drops to create space for the granules, and then rises to press the tablet.

Ejection The lower punch is raised as it passes over the ejection cam, and the pill is popped out of the die.

* * *

How do pedestrian crossings work?

The wait for the red man to turn green so you can cross the street can seem like an eternity. The truth is that depending on the type of junction, where it's located, and the time of day, the button might not be doing anything at all.

In theory, the button is connected to the traffic light at the intersection of a major road and a minor road. When pressed, the light on the major road changes from green to red within around 90 seconds, allowing the pedestrian to cross. However, sometimes the button is rendered useless; the walk signal will appear anyway in a prescribed amount of time because it's programmed to the signal patterns.

A press of the button is required at standalone pedestrian crossings, and some junctions will vary whether the pattern is affected by the button or not, depending on the time of day.

© Thinkstock

Why is it called Bluetooth technology?

Despite the technology being relatively new, the name Bluetooth actually has medieval origins. It was chosen by the largely Scandinavian team of engineers that created the wireless communications technology back in the 1990s, and is the English translation of the name of a Viking king.

When looking for a name that signified their new invention's ability to connect PCs and cellular phones, the team thought of King Harald Blåtand of Denmark, who was famous for uniting parts of Denmark and Norway with non-violent negotiations. The name's origins are also evident in the Bluetooth symbol, as it is king Blåtand's initials written in Norse runes.

* * *

What happens to Snapchat photos after you have viewed them?

Snapchat claims that photos are automatically deleted from the servers once viewed and that the photo on your phone will be deleted too. However, several people on the internet have claimed to have found ways to view snaps deleted from their phones, although new versions and updates of Snapchat have tried to prevent this.

In general, electronic files aren't actually erased when you hit the delete button. The file will be marked as deleted and disappear from view, but it's still there. The file's data will remain stored on your device until it is overwritten, so images can still be found if you know where to look.

How do rechargeable batteries work?

All batteries rely on chemical reactions to produce an electric current. Inside a battery are two electrodes made of different sorts of metal, named an anode and a cathode, and an electrolyte, often an acid. Chemical reactions between the electrodes and electrolyte create a flow of electrons from anode to cathode when the battery is connected – an electric current. In the process the electrodes and electrolyte gradually become depleted as they react with each other. In a non-rechargeable battery this reaction is irreversible, and the battery will eventually stop working. When a rechargeable battery is charging, an electric current is passed the opposite way through the battery. This reverses the chemical reaction and rejuvenates the electrodes and electrolyte to a state where they can once again produce electricity. However, even a rechargeable battery can only be recharged a certain number of times before it can no longer hold a charge.

> "When a rechargeable battery is charging, an electric current is passed the opposite way through the battery"

What happens when files and photos are deleted off a computer?

When you delete a file on a computer you probably think it's gone forever, but it's not. Deleting a file just removes the label that tells the computer the file is there. All the data that used to be part of the file will still be able to be found somewhere on your hard disk.

It's a bit like taking the cover off a book, but leaving all the pages behind – the book may be gone, but the information is ultimately still there. The file only really gets erased when the computer eventually stores something new where the old file used to be on the disk.

How do auto-flush toilets work?

With an automatic toilet, you'll probably spot a small black circle nearby that looks a bit like a button – it's an infra-red sensor. This detects body heat, and is connected to an electronic valve inside the water tank. The sensor is triggered when you wave your hand in front of it or move away from the toilet, and sends a signal to the valve to empty the water from the tank. This flushes the toilet and the tank is then refilled. Electric toilets could be hazardous if the water and electricity mixed, so most are battery powered for safety.

© Thinkstock

How do hotel key cards work?

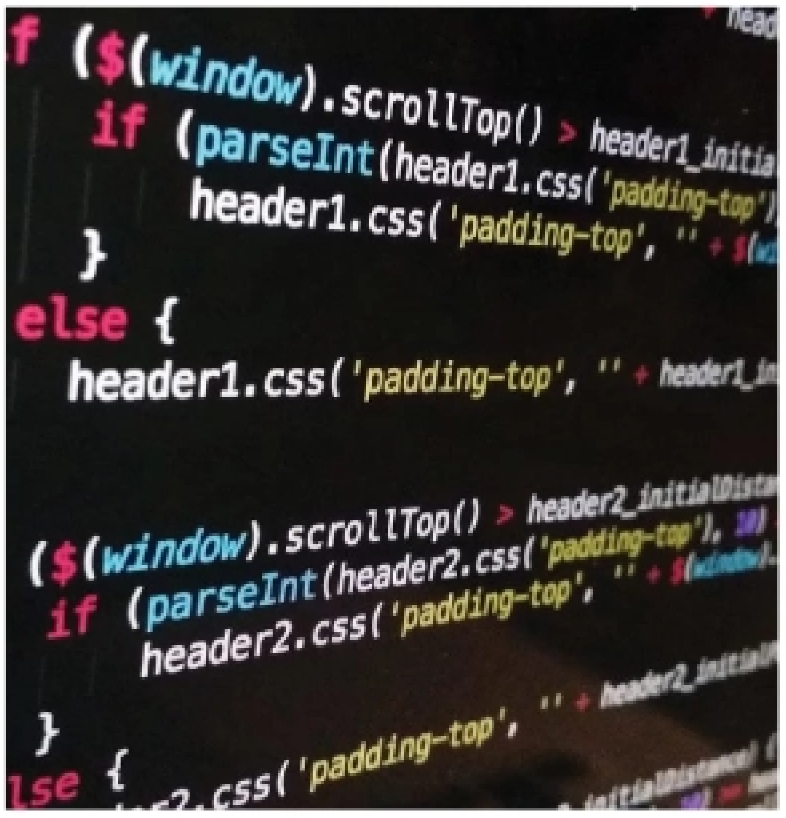
There are many types of key card systems used around the world, but their principles are all fundamentally very similar. When you check in to a hotel, the hotel receptionist uses a machine to store a code onto a magnetic strip or computer chip on your key card.

This code matches the one stored by your hotel room's electronic lock, which reads the code when you insert the card, and then switches on a small motor to unlock the door to your room.

To change the code for each new guest, the lock is either sent a new code by a network, or the card and lock have the same preset list of codes. They can then be instructed to use the next one in the sequence when required.

© Getty

> “To create a programming language, you first need to define its words and rules”



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How is a programming language created?

Deep down, computer hardware can only understand very basic commands written in machine code. As machine code is basically just ones and zeros, it's difficult for people to understand. Programming languages allow us to instruct computers using concepts and words more like human language, like LOAD and DO, and convert these to machine code that the computer can understand. To create a programming language, you first need to define its words and rules.

You then need to work out how instructions in your language relate to instructions in machine code, a bit like translating to a foreign language. Next, you need to create a program called a compiler or an interpreter, which turns programs written in your language into machine code for the computer. It's a complicated process, and new programming languages are often written using existing languages to try to make it easier.

Space

60 What future could we have in space?
66 How fast are you moving?
66 How are spacecrafts docked?
67 What are white holes?
68 What animals have been to space?
69 How far can we see?
70 How do frozen worlds form?
70 How do we search for super-Earths?
71 What near misses will Earth have?
72 What is the Sun made up of?
74 Bitesize Q&A

What future could we have in SPACE?

Just because we were born on Earth, it doesn't mean we're destined to stay here

It goes without saying that the Earth is the perfect home for us. From the last universal common ancestor to the human beings that have spread across the planet today, we've been slowly fine-tuning ourselves through evolution to perfectly suit our environment.

But it may not be that way forever. We continue to burn fossil fuels in abundance and our population continues to boom, which is damaging our environment and placing a strain on resources. How long our planet can continue to support the ever-growing population of humans is a major cause for concern.

Aside from our self-inflicted destruction, we may still be forced to move elsewhere. We already know of at least one mass-extinction event that's been caused by an asteroid colliding with our home, and what happened to the dinosaurs could also happen to us. An asteroid crashed into Siberia in 1908, causing devastation to the local environment. Fortunately, it was only about 50 metres wide and our species survived, but much larger comets and asteroids fly through our galactic neighbourhood fairly regularly. How long until the next one hits?

So an extraterrestrial future, at some point at least, seems inevitable. But rather than fleeing into the expanses of space, there are also many positive reasons for the human race to broaden its horizons.

Travelling far away could improve life at home in many ways. By journeying to, and mining from, asteroids, we could harvest many desirable materials and save our planet's deposits. By spreading our species across the cosmos we'd also be safer from a universal extinction event, preserving our – as far as we know – unique intelligence and consciousness. And having fewer humans on Earth can only be a good thing, as the biodiversity of other species could expand and thrive in our absence.

Perhaps just as importantly, what an inspirational step it would be for humankind. We're born explorers; we love encountering and discovering the unknown. What better way to scratch this itch than by embarking towards the final frontier?

In this feature, we'll explore the possible future of humanity as an interplanetary species. It's a goal that many around the world are already working towards.

Where could we go?

The Solar System and beyond is full of planets and moons, but which is best?

When surveying potential options for our new home that are within reach, we may feel our choices are limited. But with the correct technology, we'd have quite a few to pick from, even in our own Solar System. We could potentially colonise another planet, a moon, or even space itself.

Currently the most romantic choice seems to be Mars. As a close neighbour that could potentially house an enclosed habitat, it's certainly appealing. But we needn't limit our imaginations to just Mars. Every night another potential home rises to greet us.

We already know we can get to the Moon, and its closeness to Earth makes it a candidate. Materials, supplies and even new colonists could be transported there with ease. Due to the relatively short distance (astronomically speaking) contact with Earth would also be much quicker.

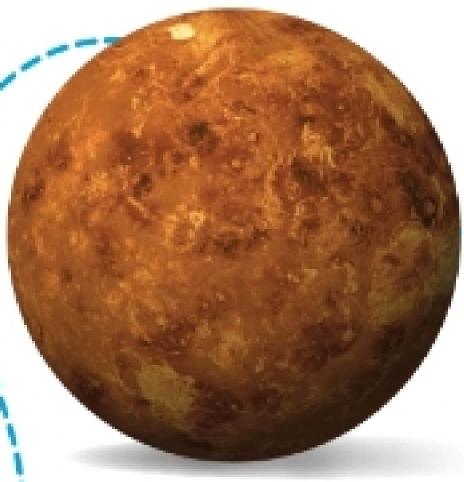
But, unlike Mars, the Moon is almost completely devoid of water. However, the same can't be said for some of Saturn's moons. Some of these satellites even have liquid water, which spurts out from oceans below their surface. They could offer a potential way for us to harvest water, an integral ingredient for survival.

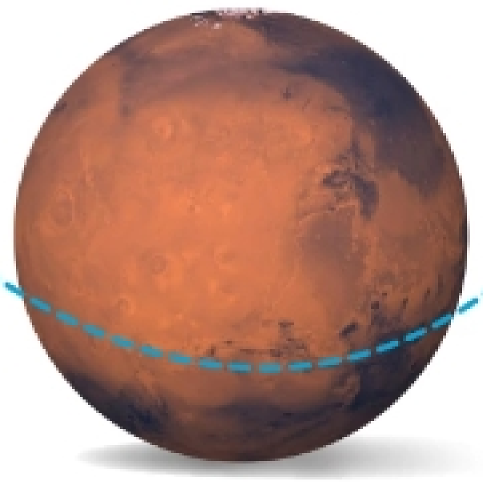
Once settled on a planet or moon, our eventual goal would be terraforming. This would involve generating gases to form an atmosphere like Earth's, allowing life to flourish. But this would be no small task, so perhaps getting to these planets would just be the easy part.

Billions and billions of worlds exist beyond our Solar System, but reaching them will be challenging

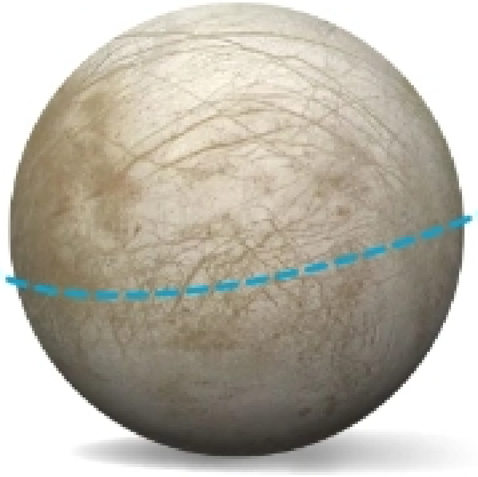
Possible destinations

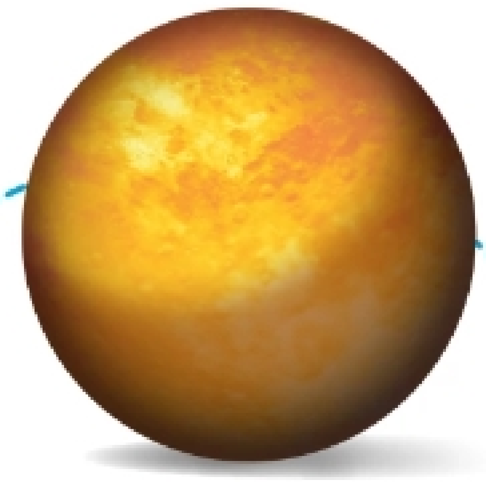
Astronomers have identified a whole host of worlds that could potentially become our new home

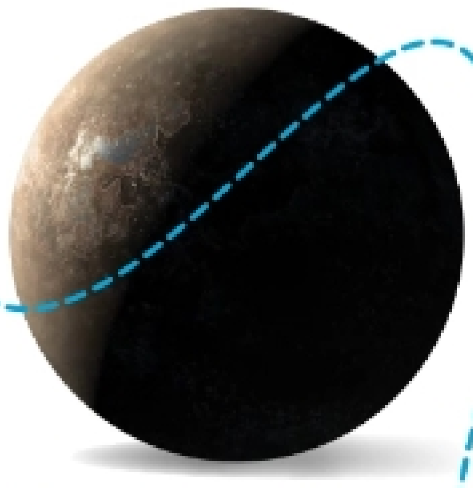

Venus
261mn km
Although sometimes described as 'Earth's sister' due to its similar mass and close proximity to us, Venus' closeness to the Sun has raised surface temperatures to 462°C – so we'd have to live in floating cities in the clouds.


Mars
225mn km
The extensive research that's currently being conducted on the surface means we'd be better prepared if we eventually settle there. We've already identified buried ice and also understand the dangers that await us.

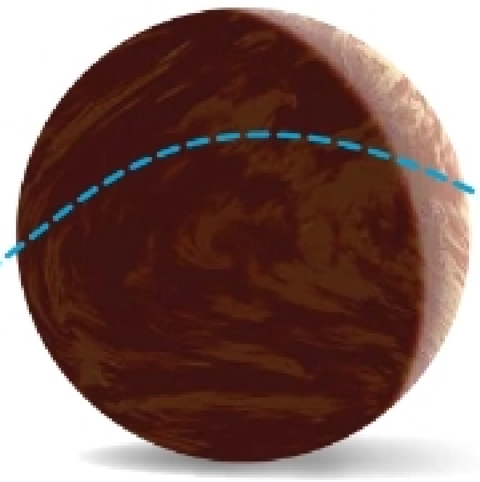
The Moon
384,400km away
Being the closest large space object to us makes the Moon a strong candidate for the first extraterrestrial colony. Materials and people could be transported to and from Earth much more easily than elsewhere.

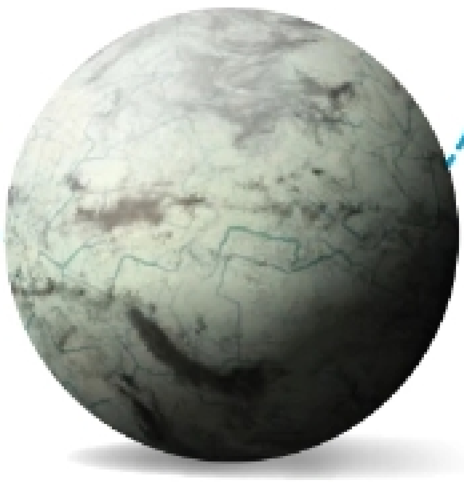

Europa
628.3mn km
With plenty of oxygen and oceans of liquid water, Europa could be one of the best places for life in our Solar System. But it's low gravity and freezing temperatures may mean it's better for us to reside in an orbiting space habitat.


Titan
Approx. 1.4bn km
Saturn's largest moon has lakes, clouds and rain – but they're not made of water. On Titan, methane exists in liquid form and cyanide gas floats over the surface. Underground habitats would provide the most protection.


Proxima Centauri b
4.2 light years
This planet is exciting as it orbits our closest stellar neighbour. It's probably also a victim of constant bombardment from solar flares as it's so close to its star, but it's a rocky planet with the right temperatures for liquid water.

GJ 667 Cc
23.6 light years
This planet is also within a desirable range of its local star for it to possess liquid water. Unfortunately, the dwarf star is likely to produce solar flares. To settle there, we'd have to shield ourselves from this radiation.

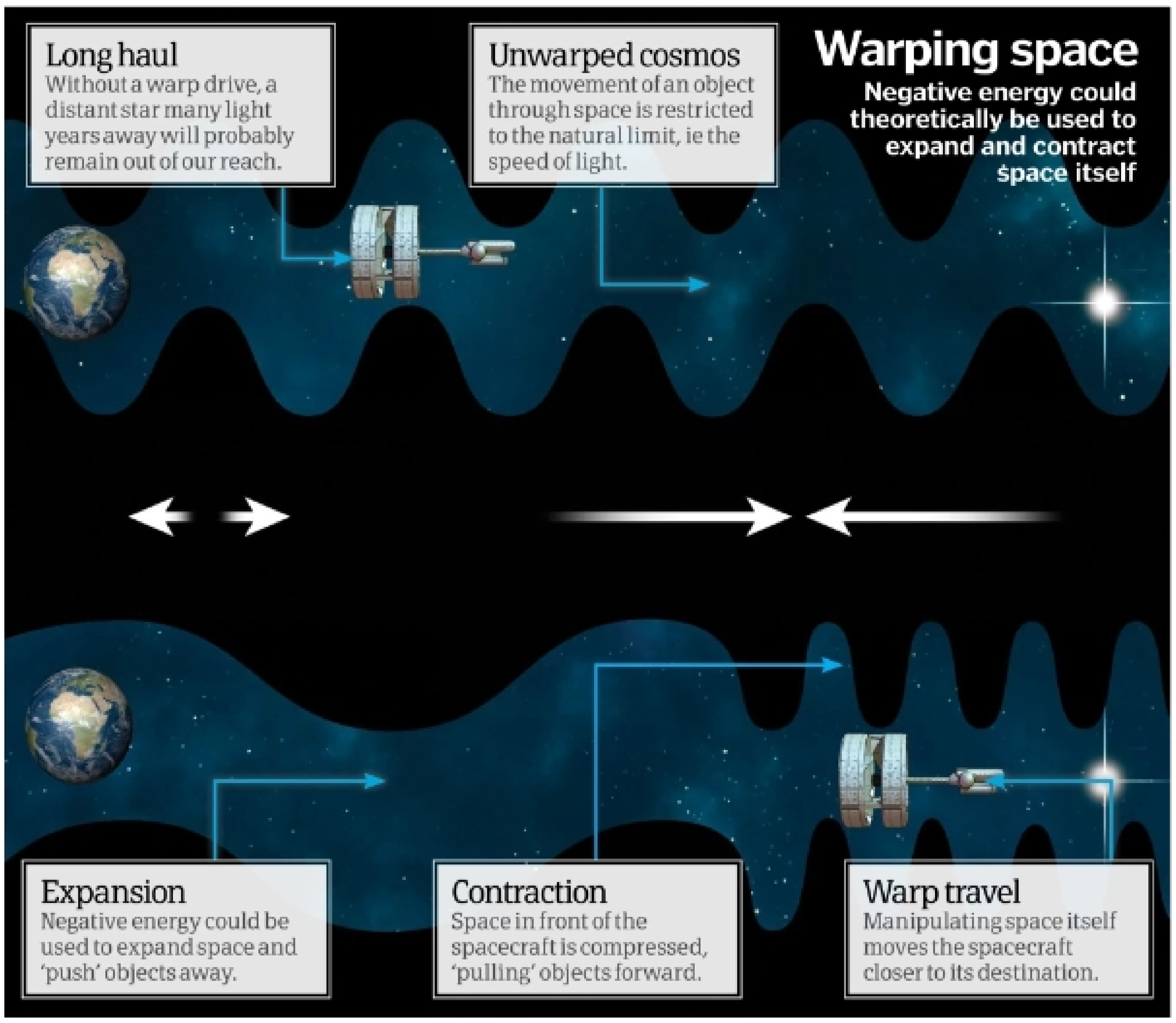

Wolf 1061 c
13.8 light years
This planet orbits its star in the 'Goldilocks zone', meaning that it is neither too hot nor too cold for liquid water. And it doesn't appear to get hit with too much solar radiation either, making it a potential safe haven for humans.


Kapteyn b
12.8 light years
This planet could be one of the most habitable of all known space objects. It's heavy, has favourable temperatures for liquid water, and it is thought to be twice as old as the Earth – so it may already in fact host life.

© Thinkstock; NASA

How would we move?

Overcoming the distances between systems is one of our biggest challenges



Warping space

Negative energy could theoretically be used to expand and contract space itself

Long haul
Without a warp drive, a distant star many light years away will probably remain out of our reach.

Unwarped cosmos
The movement of an object through space is restricted to the natural limit, ie the speed of light.

Expansion
Negative energy could be used to expand space and 'push' objects away.

Contraction
Space in front of the spacecraft is compressed, 'pulling' objects forward.

Warp travel
Manipulating space itself moves the spacecraft closer to its destination.

Even if we decided to 'only' venture as far the nearest star cluster from our Solar System, we'd still be talking huge distances. More than four light years, in fact. That means that even if we were travelling at near the speed of light it would still take us years, and today's rocket engines can't even reach one per cent of light speed.

But despite the mammoth stretch involved it may be worth our while to venture there. But how would we do it? The answer may lie with designing a new propulsion system that's capable of much higher speeds than the rocket-fuelled ones of today. The majority of such designs remain in the theoretical phase, but some have the potential to increase velocities much closer to the speed of light. This means we could traverse the gap between systems in perhaps decades, rather than millennia.

What makes these innovative engine concepts so interesting is their choice of fuel, and how we can best make use of them. Ionised gases, interstellar hydrogen and even antimatter have all been proposed as potential options, and could, in principle, be employed to shoot us quickly towards distant stars. Or, rather than high-speed travel, how about bending space-time around us instead?

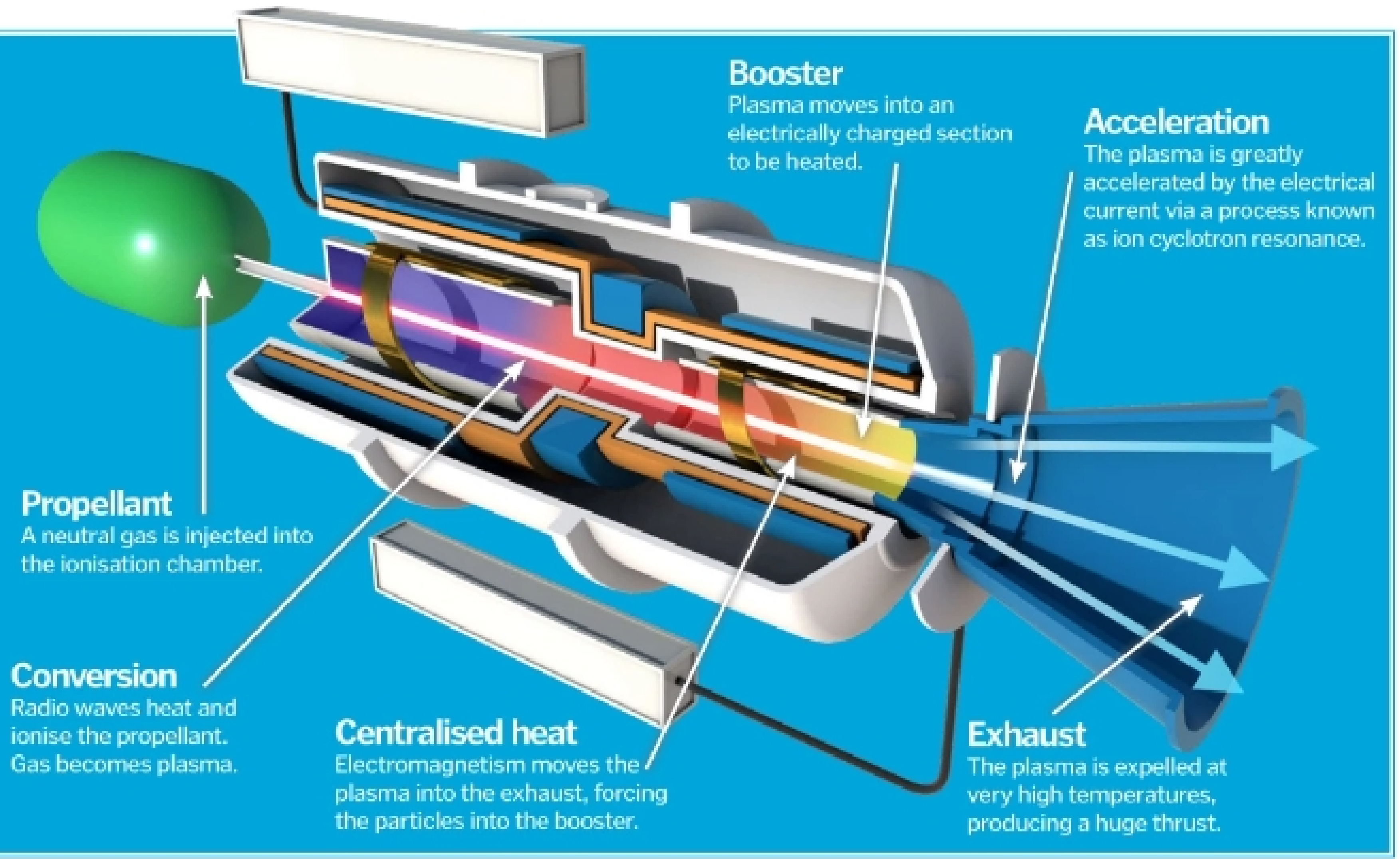
Of course, it sounds impossible, but according to Einstein's theory of relativity, it isn't. And this knowledge has given birth to the idea of a warp drive. By using an elusive form of energy known as negative energy, we could expand and contract space around spacecraft in order to move them closer to a goal in a time span that would otherwise be completely impossible.

For the foreseeable future, warp drives are nothing more than just an abstract idea. But some of the other designs are in development now, and could be ready for blast-off a lot sooner than we think.

The VASIMR engine

Today's rockets are launched by a chemical reaction, which involves quickly combusting a lot of fuel to get spacecraft off the ground. But although this approach has worked for us so far, chemical reactions are inefficient, and will be largely ineffective for taking us into the far reaches of space.

The Ad Astra Rocket Company's VASIMR (Variable Specific Impulse Magnetoplasma Rocket) offers a much more efficient, and faster, engine design. By supercharging simple gas into a viable propellant, spacecraft will require less fuel and will be able to travel consistently at higher speeds. This would allow us to travel further and faster than ever before.



Booster
Plasma moves into an electrically charged section to be heated.

Acceleration
The plasma is greatly accelerated by the electrical current via a process known as ion cyclotron resonance.

Propellant
A neutral gas is injected into the ionisation chamber.

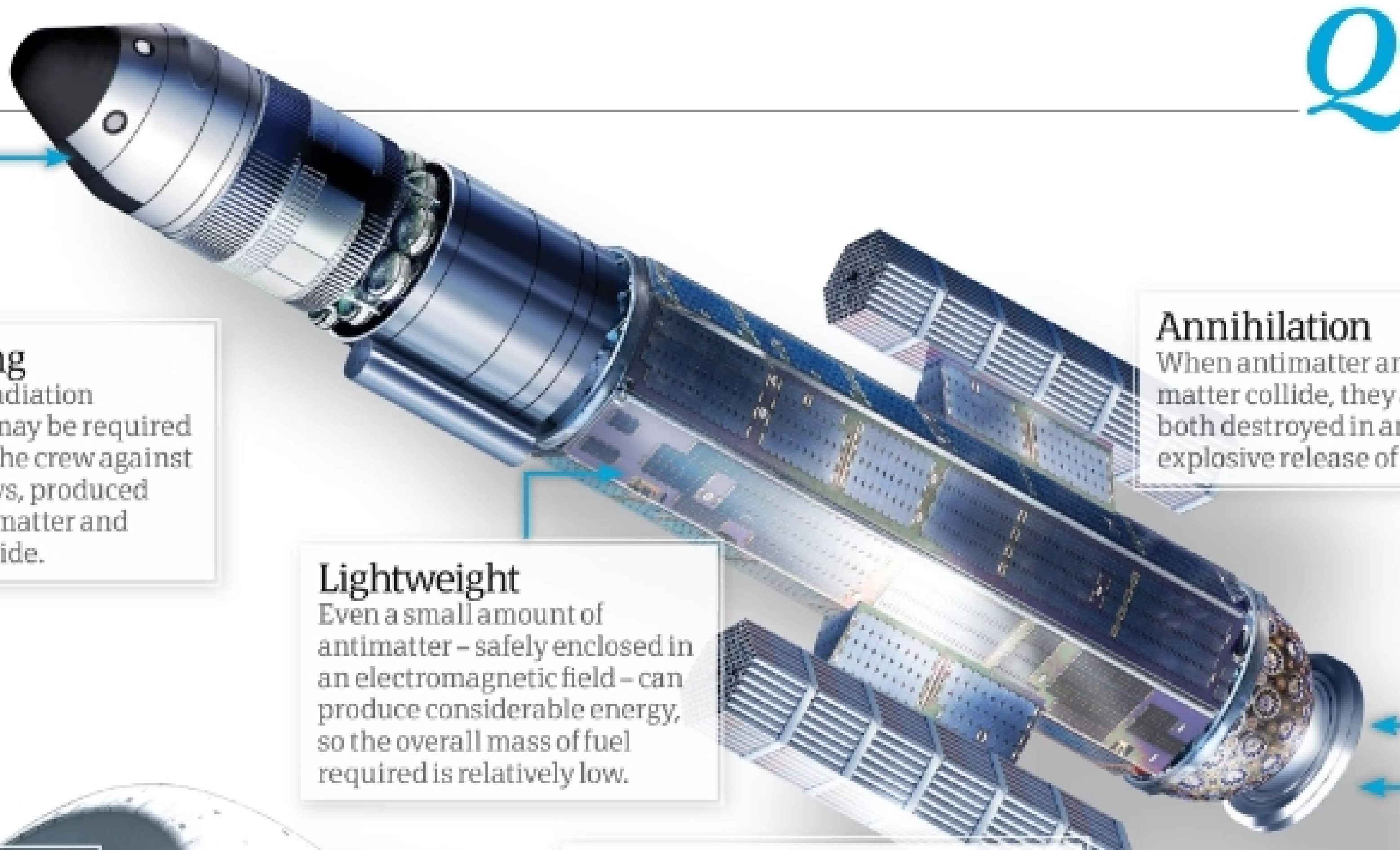
Conversion
Radio waves heat and ionise the propellant. Gas becomes plasma.

Centralised heat
Electromagnetism moves the plasma into the exhaust, forcing the particles into the booster.

Exhaust
The plasma is expelled at very high temperatures, producing a huge thrust.

Powering tomorrow's spacecraft

Plasma, antimatter and negative energy may be our tickets to deep space exploration



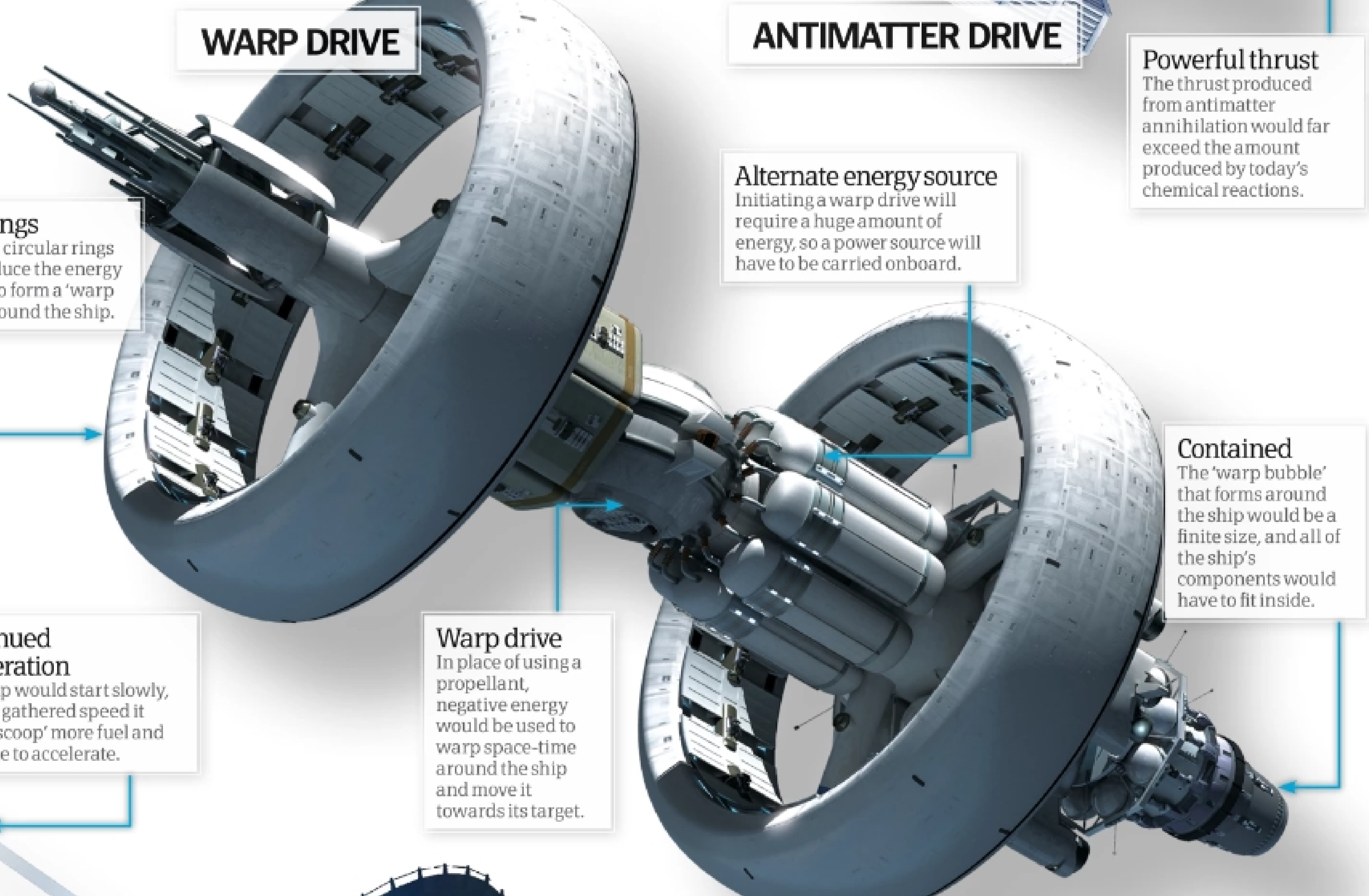
ANTIMATTER DRIVE

Shielding
A form of radiation shielding may be required to protect the crew against gamma rays, produced when antimatter and matter collide.

Lightweight
Even a small amount of antimatter – safely enclosed in an electromagnetic field – can produce considerable energy, so the overall mass of fuel required is relatively low.

Annihilation
When antimatter and matter collide, they are both destroyed in an explosive release of energy.

Powerful thrust
The thrust produced from antimatter annihilation would far exceed the amount produced by today's chemical reactions.



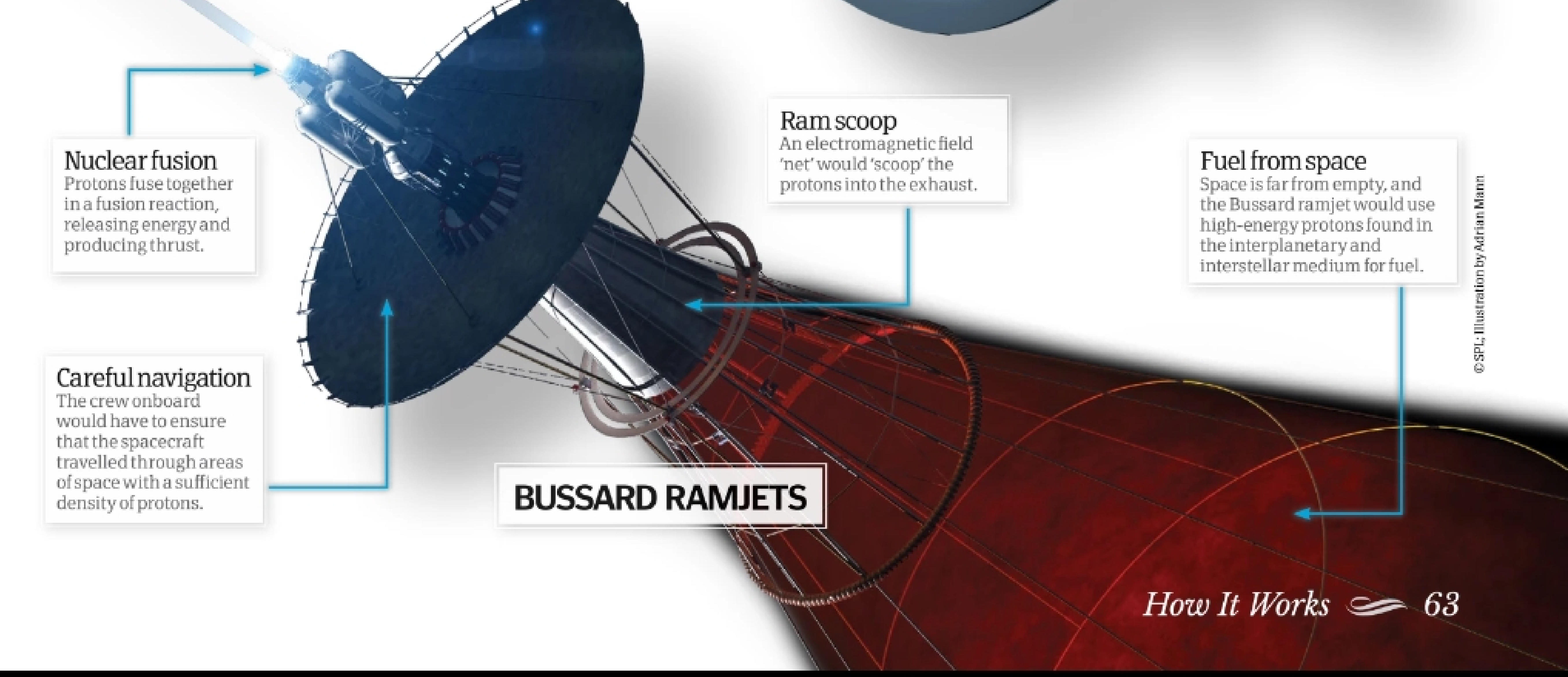
WARP DRIVE

Warp rings
Two thick, circular rings help to reduce the energy required to form a 'warp bubble' around the ship.

Alternate energy source
Initiating a warp drive will require a huge amount of energy, so a power source will have to be carried onboard.

Contained
The 'warp bubble' that forms around the ship would be a finite size, and all of the ship's components would have to fit inside.

Warp drive
In place of using a propellant, negative energy would be used to warp space-time around the ship and move it towards its target.



BUSSARD RAMJETS

Continued acceleration
This ship would start slowly, but as it gathered speed it would 'scoop' more fuel and continue to accelerate.

Nuclear fusion
Protons fuse together in a fusion reaction, releasing energy and producing thrust.

Ram scoop
An electromagnetic field 'net' would 'scoop' the protons into the exhaust.

Fuel from space
Space is far from empty, and the Bussard ramjet would use high-energy protons found in the interplanetary and interstellar medium for fuel.

Careful navigation
The crew onboard would have to ensure that the spacecraft travelled through areas of space with a sufficient density of protons.

©SPL; Illustration by Adrian Mann

Where would we stay?

Giant space habitats could allow us to bring a slice of Earth with us into the cosmos

An extraterrestrial civilisation of humans, wherever they may be, would need to rely on a home that could provide a similar amount of nourishment and protection as we receive on Earth. As we would need to consider air, heat, radiation, water, gravity, food, and ample habitable space, it would be a monumental task.

We know that nowhere nearby can provide all of these necessities, and terraforming will be a long, difficult, and perhaps impossible process. So maybe the easiest way to control these variables would be to assemble our own space habitat. This gigantic structure could either be a new permanent home, or a means to set off on a multi-generation migration.

The second option would be a quest unlike anything humanity has ever faced, and would involve many generations spending their entire lives in space, safely enclosed in a living habitat. But our universe is a very big place, and this may be our best way to explore it.

By realising our ambitions of mining asteroids we could gather the required materials, and by taking advantage of the centripetal force produced by spinning objects, we could simulate gravity. This project would be undeniably huge, but humans are capable of achieving great things, and we have an idea of how we could do it. In stark contrast to the sterile, squashed spacecraft we're used to, these settlements would be a true home away from home, containing many of the pleasures we enjoy on our planet's surface.

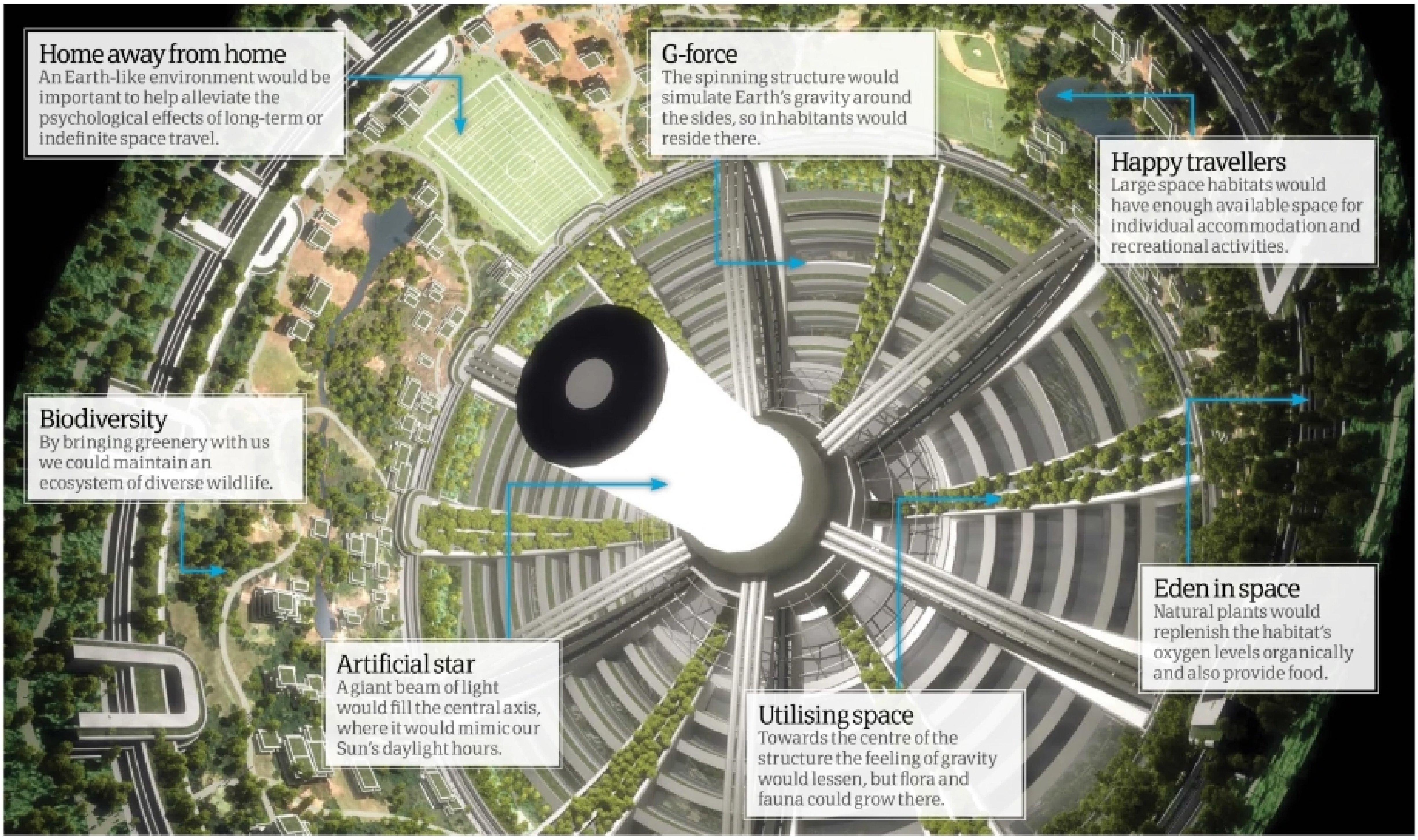
There is also one more aspect to consider about this possible future. If some colonists do choose to remain on Earth, others in space, and others on distant planets and moons, then our species may eventually begin to diversify. Remaining apart for many generations, throughout consistent subjection to different forces of gravity and atmospheres, could eventually mean that some of us may not be simply humans any longer. Our future in space has the potential to create a new alien species: our future descendants.

In the distant future we really could be spoiled for choice, so let's get to know our options and take a tour of a potential space settlement.

Constructing a giant space habitat would be a monumental task for humanity

Making space home

A habitat like the Kalpana One design would allow us to travel through space in style



Home away from home
An Earth-like environment would be important to help alleviate the psychological effects of long-term or indefinite space travel.

G-force
The spinning structure would simulate Earth's gravity around the sides, so inhabitants would reside there.

Happy travellers
Large space habitats would have enough available space for individual accommodation and recreational activities.

Biodiversity
By bringing greenery with us we could maintain an ecosystem of diverse wildlife.

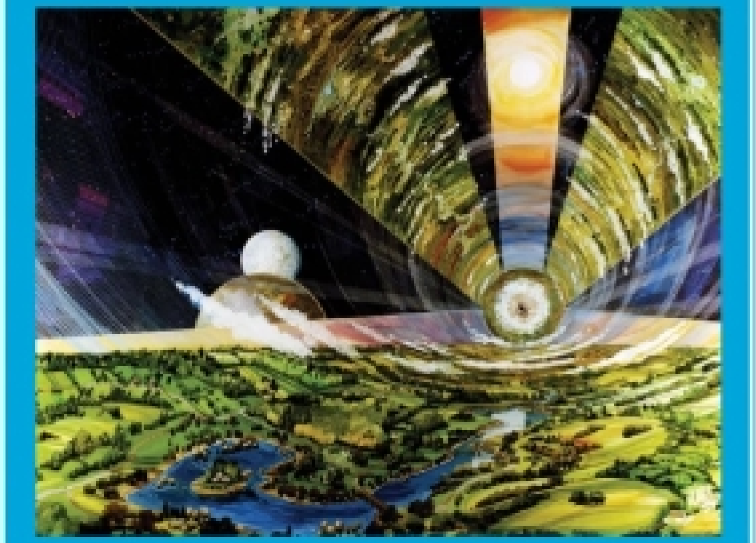
Artificial star
A giant beam of light would fill the central axis, where it would mimic our Sun's daylight hours.

Utilising space
Towards the centre of the structure the feeling of gravity would lessen, but flora and fauna could grow there.

Eden in space
Natural plants would replenish the habitat's oxygen levels organically and also provide food.

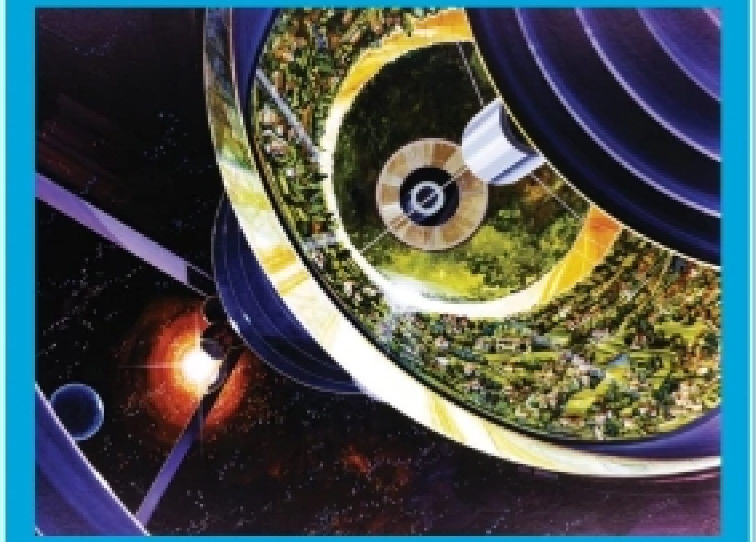
Retro concept designs

In the 1970s, a NASA-funded team inspired a generation of space enthusiasts with three spinning structures



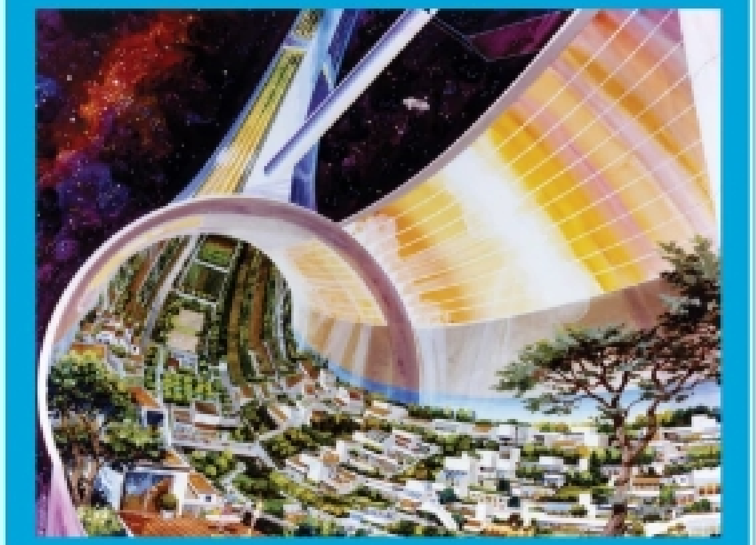
O'Neill Cylinder

Three strips of land and three gigantic sections of glass would be assembled in a structure approximately eight kilometres wide and 32 kilometres long. Two of these structures could be positioned in a counter-rotating pair to stabilise the cylinders, which would otherwise rotate across their long axis as they spin.



Bernal Sphere

Originally proposed by scientist John Bernal in 1929 before it was adapted in the 1970s, this design is similar to a globe in shape, only this time we would live on the inside of a hollow shell, rather than on the outside. Earth-like gravity would be felt along the equator and lessen as you neared the poles.

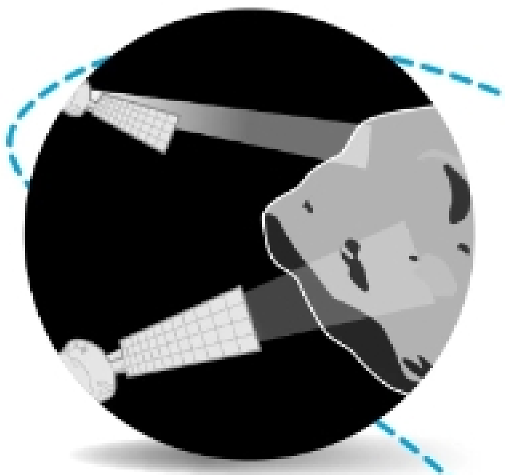


Stanford Torus

This concept would involve residents living inside a ring structure, which could either have a transparent ceiling or even an open top. The spinning motion would keep most of the atmosphere pressed within the rings, so spacecraft could easily come and go.

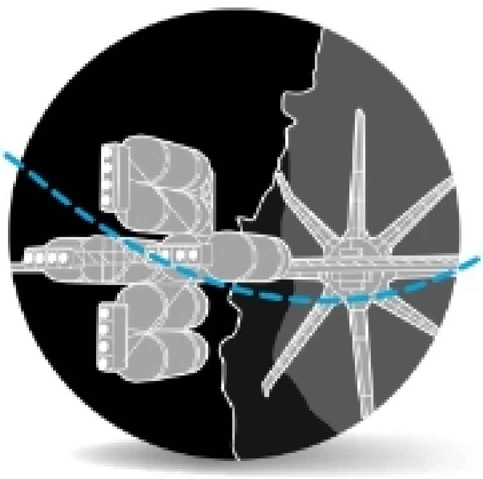
Space jobs

A host of new careers will be up for grabs on our future space settlements



Extraterrestrial surveyor

Gathering sufficient resources will be one of the most important jobs for a space habitat, and asteroids will be the place to get them. A surveyor will assess these space rocks and decide on the best mining locations.

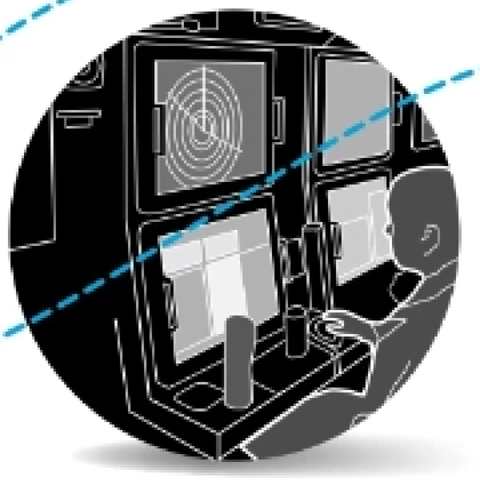


Asteroid miner

It is unlikely that a miner will go out on spacewalks and manually operate the equipment, as this would be extremely dangerous. Instead, they will be in charge of remotely operating and overseeing the machinery from the safety of their space habitat.

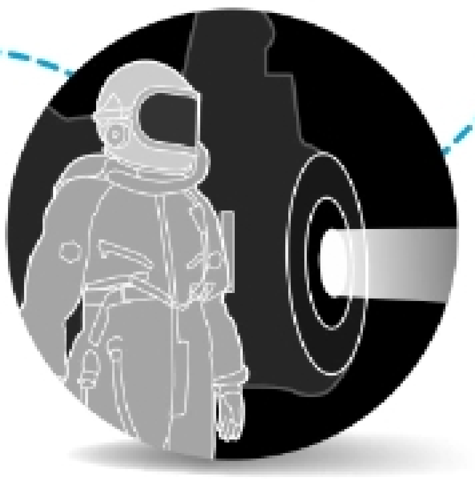
Atmosphere overseer

In this role, you'd have the lives of all of the other space inhabitants in your hands. Maintaining an Earth-like atmosphere in a space habitat will involve regulating oxygen and carbon dioxide levels, temperature and the amount of ultraviolet light.



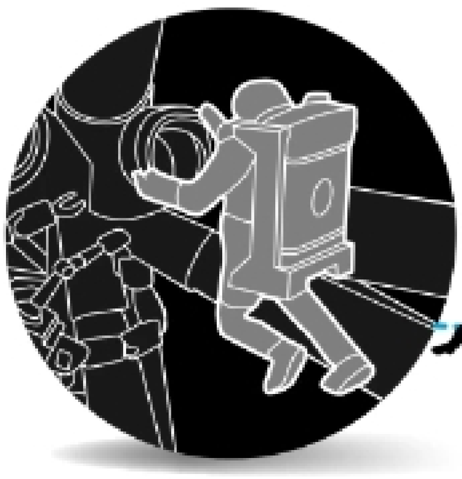
Communications and navigations specialist

One space habitat won't be enough to carry everyone, so the multiple ships will need a way to communicate. As well as sending and receiving signals, these specialists will ensure their ship stays on the right path.



Propulsion engineer

Whatever choice of futuristic engine is used to power the movement of our habitats, it will require monitoring and most likely refuelling. Propulsion engineers will oversee these processes and ensure the engine doesn't overheat or leak radiation.

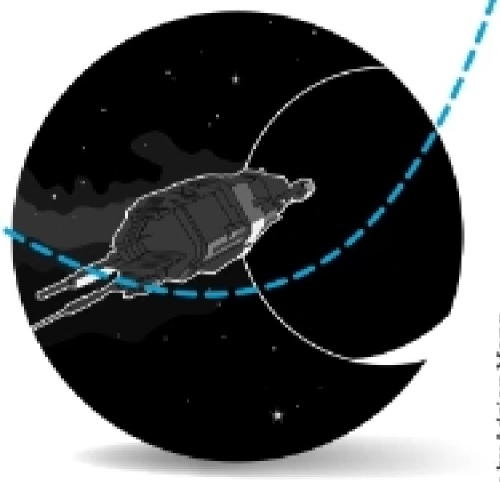


Habitat construction and maintenance

As it will be much easier to assemble huge structures in zero gravity, a construction team may well decide to build in space. They'll also repair any damage caused by space debris.

Exercise physiologist

A physiologist will make sure that the centripetal force caused by the spinning space station sufficiently mimics Earth's gravity, and will recommend weighted exercises for those who need to build more muscular strength.



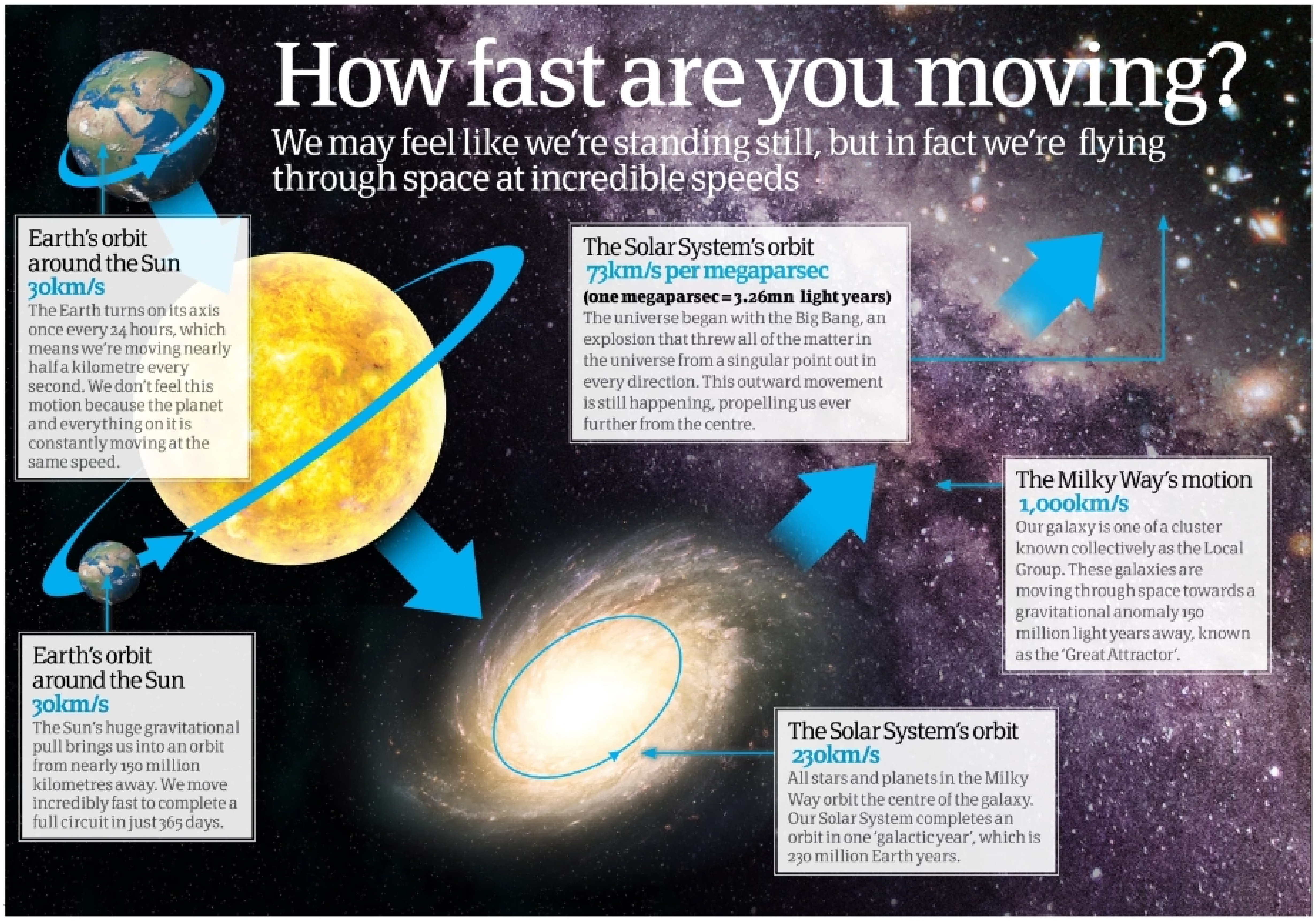
Space voyager

When exploring the unknown it may be necessary to send human scouts to an object. Smaller spacecraft usually attached to the main habitat will be used for this task, with a dedicated team of space adventurers inside.

© Bryan Versteeg; NASA; Illustration by Adrian Mann

How fast are you moving?

We may feel like we're standing still, but in fact we're flying through space at incredible speeds



Earth's orbit around the Sun
30km/s
The Earth turns on its axis once every 24 hours, which means we're moving nearly half a kilometre every second. We don't feel this motion because the planet and everything on it is constantly moving at the same speed.

Earth's orbit around the Sun
30km/s
The Sun's huge gravitational pull brings us into an orbit from nearly 150 million kilometres away. We move incredibly fast to complete a full circuit in just 365 days.

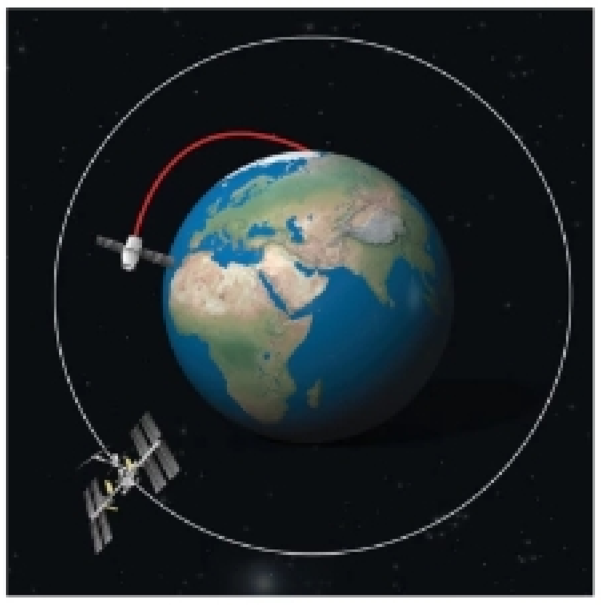
The Solar System's orbit
73km/s per megaparsec
(one megaparsec = 3.26mn light years)
The universe began with the Big Bang, an explosion that threw all of the matter in the universe from a singular point out in every direction. This outward movement is still happening, propelling us ever further from the centre.

The Milky Way's motion
1,000km/s
Our galaxy is one of a cluster known collectively as the Local Group. These galaxies are moving through space towards a gravitational anomaly 150 million light years away, known as the 'Great Attractor'.

The Solar System's orbit
230km/s
All stars and planets in the Milky Way orbit the centre of the galaxy. Our Solar System completes an orbit in one 'galactic year', which is 230 million Earth years.

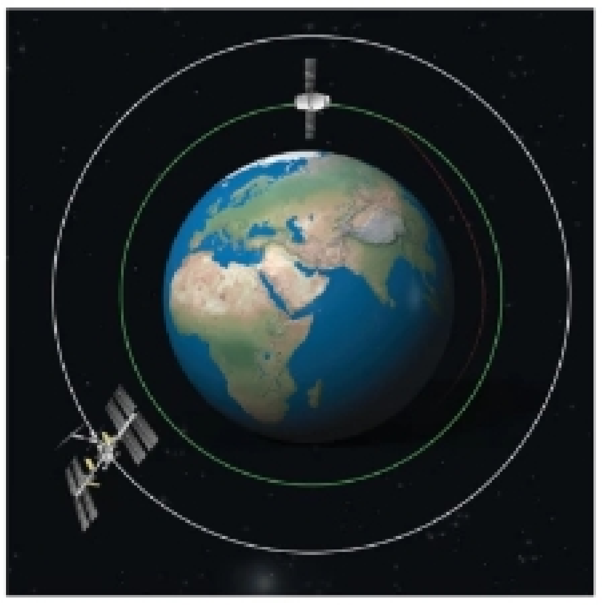
How are spacecrafts docked?

How astronauts in the Soyuz capsule board the International Space Station



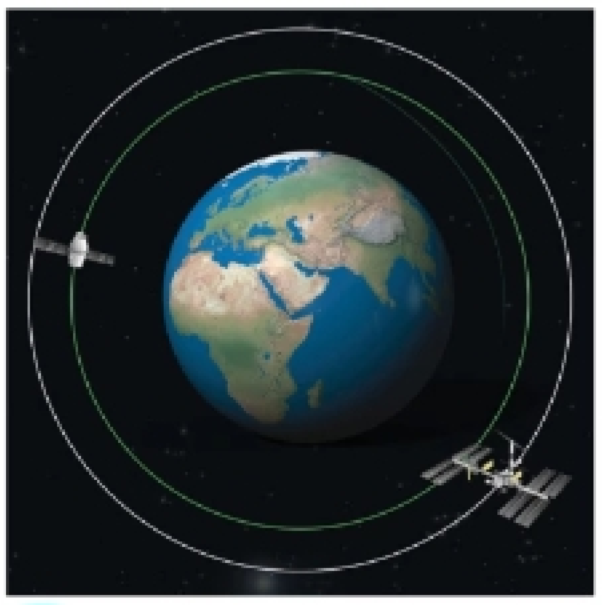
1 Reaching space

It only takes a matter of minutes to blast into space, but it can take hours or even days to reach the International Space Station (ISS). Following blast-off, the Soyuz capsule enters orbit by firing its rockets parallel to the spacecraft's direction of travel.



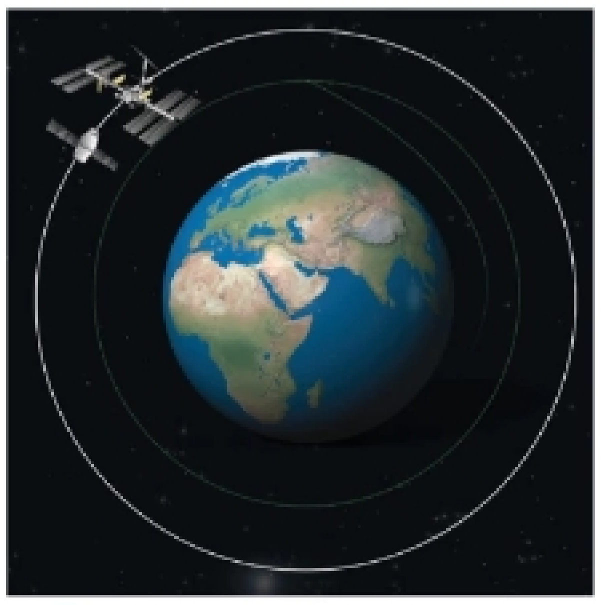
2 Transfer into higher orbit

The ISS orbits the Earth at a higher altitude, so the Soyuz has to reach it via an elliptical path called a Hohmann transfer orbit. This features two engine burns – one to take the Soyuz into the higher orbit and another engine burn to keep it there.



3 Small corrections

The Hohmann transfer orbit isn't always precise, and the Soyuz has to perform small thruster burns to manoeuvre itself into an orbit around Earth with a period of 86 minutes – four minutes faster than the slightly higher ISS, which is moving at around 28,000 kilometres per hour.



4 Overtaking the ISS

As the Soyuz is moving faster, it overtakes the ISS above it, then fires its engines again to enter another Hohmann transfer orbit that brings the spacecraft just in front of the ISS, 400 kilometres above Earth. Then the Soyuz turns around, fires its engines to slow down, and docks.

© NASA

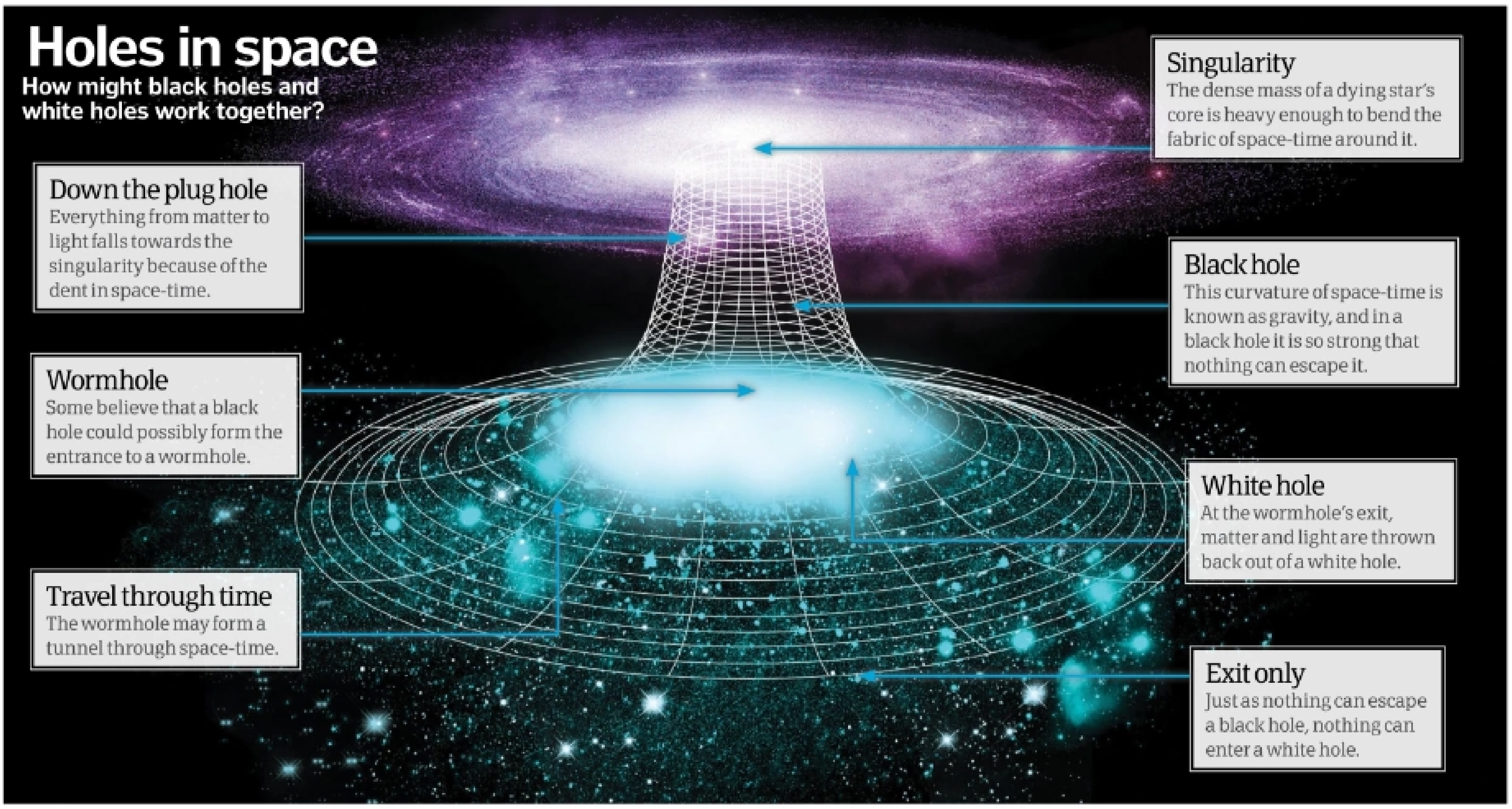
What are white holes?

Is there such a thing as a black hole in reverse?

The universe is full of black holes. These cosmic objects form when a massive star, much bigger than our Sun, collapses in on itself and dies in a spectacular supernova. The remains of this star are concentrated into a small but dense area, known as a singularity, with a very strong gravitational pull. In fact, it's so strong that everything around it, even light, gets sucked in and cannot escape, making black holes difficult to detect. What astronomers haven't yet been able to detect though, are white holes. Currently just a theoretical mathematical concept, these space objects are essentially the opposite of black holes, expelling matter and light into the universe instead of sucking it in.

One theory about the formation of white holes is that they begin as their darker counterparts. Once a black hole has engulfed as much matter as it can, it may go into reverse, expelling it all back out again to become a white hole. Alternatively, some believe that white holes may be the exit of another type of space hole, the wormhole, while others have suggested that the Big Bang began as a white hole, expelling all the of elements of the universe.

The fact remains though that, as yet, we have no proof of their existence. Although white holes have the potential to exist according to the theory of general relativity, it's thought that they would simply be too unstable to last for very long.



Holes in space

How might black holes and white holes work together?

Singularity
The dense mass of a dying star's core is heavy enough to bend the fabric of space-time around it.

Down the plug hole
Everything from matter to light falls towards the singularity because of the dent in space-time.

Black hole
This curvature of space-time is known as gravity, and in a black hole it is so strong that nothing can escape it.

Wormhole
Some believe that a black hole could possibly form the entrance to a wormhole.

White hole
At the wormhole's exit, matter and light are thrown back out of a white hole.

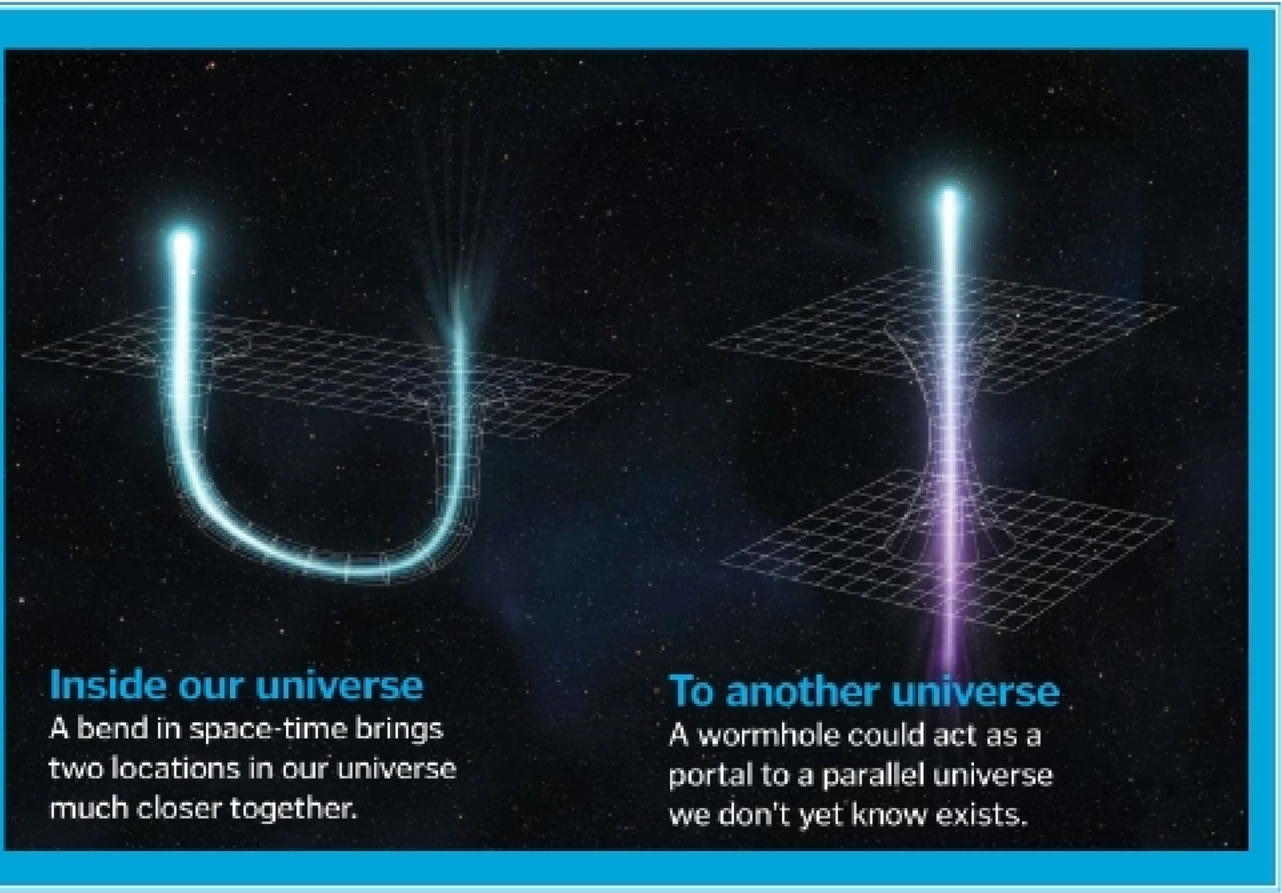
Travel through time
The wormhole may form a tunnel through space-time.

Exit only
Just as nothing can escape a black hole, nothing can enter a white hole.

What are wormholes?

Also known as an Einstein-Rosen bridge, a wormhole is a tunnel that punches through the fabric of space-time, acting as a shortcut to transport matter across the universe. If you imagine the universe as a sheet of paper, bending it in half would bring the two ends closer together. Punching a hole through the paper would then provide a much quicker route from end to end than simply drawing a line across the flattened sheet.

Although only predicted by the theory of general relativity, it is thought that a wormhole would have a black hole at its mouth, sucking in matter to then transport it through the tunnel and into the past. A white hole then, could be the tunnel's exit, throwing the matter back out into the same universe, or indeed another one we don't yet know about. Theoretically, wormholes could make time travel possible, but in reality they are likely to be far too small and unstable to transport humans.



Inside our universe
A bend in space-time brings two locations in our universe much closer together.

To another universe
A wormhole could act as a portal to a parallel universe we don't yet know exists.

What animals have been to space?

Meet the creatures who paved the way for human spaceflight

1 Fruit Flies

On board a captured Nazi V-2 rocket in 1947, these tiny pests made history. They were the first animals in space, sent to explore the effects of radiation on organisms. They returned to Earth safely by parachute.

2 Monkeys

A total of 32 monkeys have flown to space, beginning with Albert II in 1949. A decade later, a rhesus and a squirrel monkey became the first to survive the trip, experiencing over 30 times the pull of our Earth's gravity.

3 Mice

Even today, mice are ferried to and from the ISS and are key for studies in sending humans to Mars. Recently, it was discovered that astro-mice sent to deep space showed signs of liver damage.

4 Dogs

During the 1950s and 1960s, dogs were used by the USSR to investigate whether human spaceflight was feasible. The Soviets chose canines believing they could cope with the stress of the experience better than other animals.

5 Geckos

Russian scientists sent lizards to space to study how weightlessness affects reproduction. When one wriggled free of its identification collar, the geckos were filmed playing with the floating object – a rare behaviour for reptiles.

6 Cats

In 1963, the very first feline was sent into space by French scientists. The cat, known as Félicette, had electrodes implanted in her brain in order to record impulses sent back to Earth.

7 Rats

Love them or hate them, we're physiologically similar to rodents. That's why a team of 'ratstronauts' are currently being used to study how microgravity affects organisms during long stays in space.

8 Tortoise

The very first tortoise was launched into space in 1968 with wine flies and mealworms. They flew around the Moon and back to Earth, making them the first animals to enter deep space. What's more, they survived the trip!

9 Cockroaches

Cockroaches conceived on board the International Space Station were found to grow faster, run quicker and were much tougher than those born on Earth. Perhaps it's time to welcome our new insect overlords.

10 Jellyfish

What do humans and jellyfish have in common? We both orientate ourselves according to gravity. NASA raised thousands of the critters in space to test the effects and found the astro-jellies couldn't swim in normal gravity back on Earth.

Two chimpanzees, Ham (pictured) and Enos, were sent into space during NASA's Mercury Program

Miss Baker, a squirrel monkey sent to space by the US, returned alive

Laika: the first animal in orbit

Padding through the streets of Moscow, Laika – a mongrel – was plucked from obscurity to stardom. Soviet scientists reasoned that since she was capable of withstanding extreme cold and hunger as a stray dog, she would be able to endure a rigorous training schedule, which would prepare her for a trip to space in 1957.

Before being confined to the capsule – essentially a metal ball weighing around 18 kilograms – Laika's fur was sponged with a weak alcoholic solution and iodine was painted onto the areas where sensors would be placed to monitor all of her bodily functions.

There were no plans to retrieve Laika from space and she died several hours into the flight from stress and excessive heat – causes that were kept a secret for 40 years. Sputnik 2 circled the Earth 2,570 times before burning up in the Earth's atmosphere. In 2008, a monument was erected in Laika's honour, outside the Moscow facility where she was trained.

Laika was selected for the rigorous astro-training because she had survived tough conditions as a stray

© Alamy

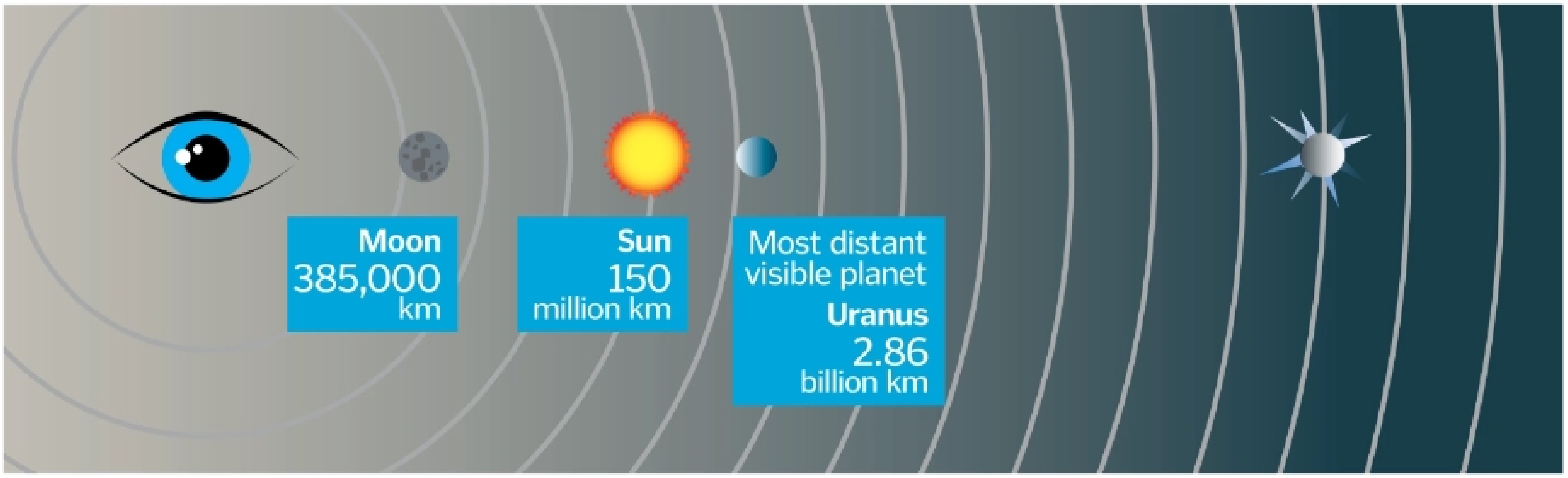
How far can we see?

Discover the most distant object visible to the naked eye in our night sky

You might think you need a telescope to explore the universe, but find yourself a suitably dark sky, free of light pollution, and even your naked eye can uncover the wonders of the universe – or, at least, our own galaxy.

When looking up at the sky, every star you are seeing is within the Milky Way. The only objects you might be able to spot that are outside it are the Andromeda Galaxy, the two Magellanic Clouds, and the Triangulum Galaxy.

This makes the latter the furthest object you can see, 2.7 million light years from Earth. You might be surprised that we can't see much outside our galaxy, considering how many stars are in the night sky. But that's just a measure of how vast space really is; there are an estimated 100 billion stars in our galaxy alone. Other galaxies are simply too far away to appear big in the sky, and require large telescopes like Hubble to be explored. In our galaxy, the furthest star you can see is likely to be V762 Cas, more than 16,000 light years away.



What is dinner like in space?

The ultimate out-of-this-world dining experience is not as glamorous as it sounds

British chef Heston Blumenthal is renowned for his experimental approach to cooking, but his latest challenge took food science to new heights. In collaboration with the UK Space Agency, Blumenthal created a selection of dishes for astronaut Tim Peake to enjoy on board the International Space Station.

NASA has strict regulations dictating what food can go into space and how it must be prepared, so sending restaurant-quality meals into orbit is no easy task. Everything must be heated to 140 degrees Celsius for two hours to kill off any bacteria that could make the crew ill, while anything that creates crumbs is strictly forbidden – they could easily float into instruments or equipment and could potentially cause serious damage – not a risk worth taking.

Eating in space is not always a particularly enjoyable experience, either. Microgravity causes body fluids to pool around the astronauts' heads, which compresses their sinuses. This affects their sense of smell and taste, so strong flavours are needed to stop food tasting bland. Another factor Blumenthal had to consider was the psychological impact of a six-month stint on the ISS. He created some of Peake's favourite dishes – including space-friendly bacon sandwiches, beef stews and Thai curries – to remind him of home.

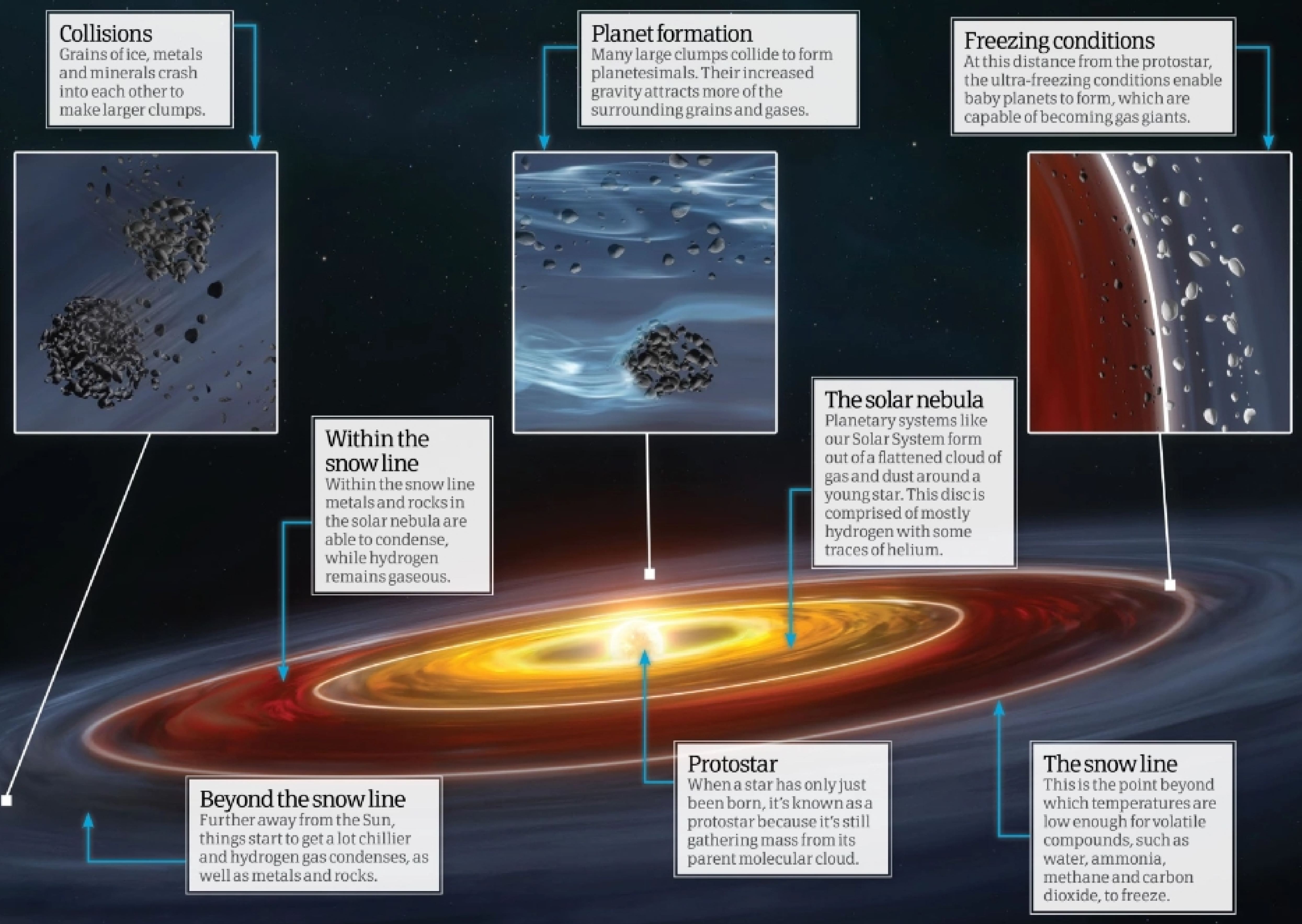
To stop food floating away, it is attached to the table with Velcro or elastic cables

Prior to launch, Blumenthal spent two years developing Major Peake's meals

© UKSA_Tim Peake_Heston Blumenthal_NASA

How do frozen worlds form?

Icy planets exist beyond the Solar System's snow line



Collisions
Grains of ice, metals and minerals crash into each other to make larger clumps.

Planet formation
Many large clumps collide to form planetesimals. Their increased gravity attracts more of the surrounding grains and gases.

Freezing conditions
At this distance from the protostar, the ultra-freezing conditions enable baby planets to form, which are capable of becoming gas giants.

Within the snow line
Within the snow line metals and rocks in the solar nebula are able to condense, while hydrogen remains gaseous.

The solar nebula
Planetary systems like our Solar System form out of a flattened cloud of gas and dust around a young star. This disc is comprised of mostly hydrogen with some traces of helium.

Beyond the snow line
Further away from the Sun, things start to get a lot chillier and hydrogen gas condenses, as well as metals and rocks.

Protostar
When a star has only just been born, it's known as a protostar because it's still gathering mass from its parent molecular cloud.

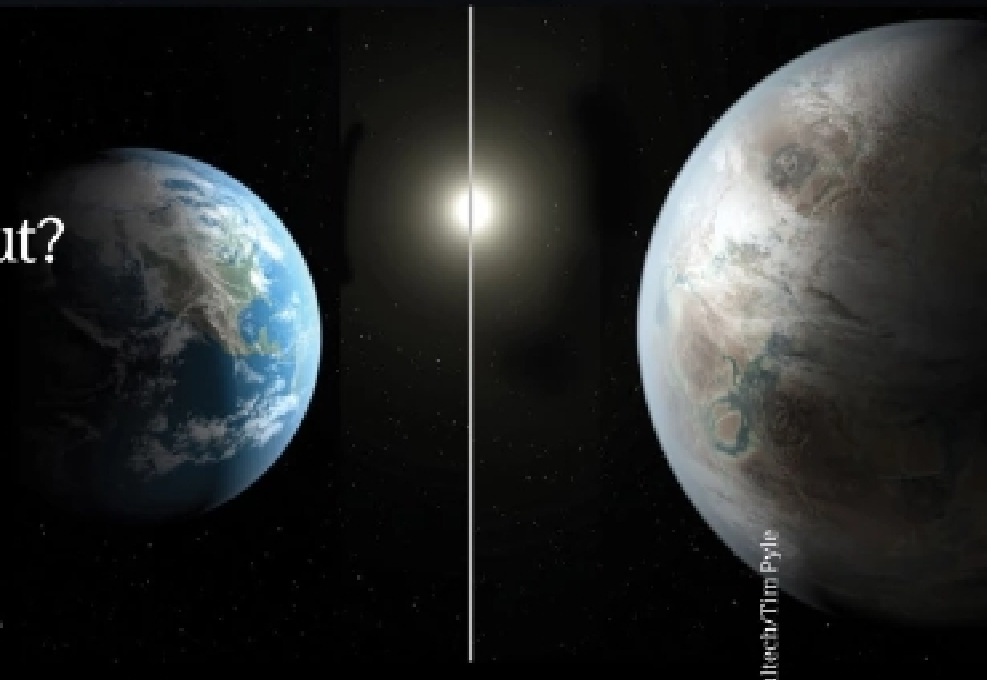
The snow line
This is the point beyond which temperatures are low enough for volatile compounds, such as water, ammonia, methane and carbon dioxide, to freeze.

How do we search for super-Earths?

There are rocky planets bigger and more massive than Earth orbiting stars many light years away, but why do we seek them out?

Over the last decade or so, astronomers have discovered that there are rocky planets up to ten times more massive than Earth orbiting other stars. They call them 'super-Earths', although that can be misleading as they may look nothing like our planet at all. They are, however, the easiest rocky exoplanets that scientists can detect. Their hefty mass means their gravity causes stars to wobble to a greater extent, giving away their presence, while their large diameter causes a dip in brightness when they are seen transiting across the face of their star.

Could they support life? It's possible – some super-Earths have been found in the habitable zones of stars, where the temperature would allow liquid water to exist. The conditions wouldn't be the same as on Earth, however, as surface gravity would be stronger, the geological activity may be different and the atmospheres are often found to be thick, which makes it easier to study the gases present. Above all, astronomers are invested in the search for super-Earths because we have none in our Solar System. That means they are among the most alien of planets we have discovered so far.



An artist's impression of a super-Earth (right) in the habitable zone of a star, compared to Earth (left)

© NASA Ames/JPL-Caltech/Tim Pyle

What near misses will Earth have?

Don't panic! The science behind sensationalist headlines explained

Headlines of an asteroid *Armageddon* may sell papers, but in reality these space rocks rarely pass within the Moon's orbit. In February, NASA announced that the asteroid 2013 TX68 could pass as close as 17,000 kilometres, or as far as 14 million kilometres from Earth's surface. It is this huge range of uncertainty that often causes a stir among media outlets; when experts appear to be so unsure, it can seem somewhat unsettling to those of us who don't really understand it.

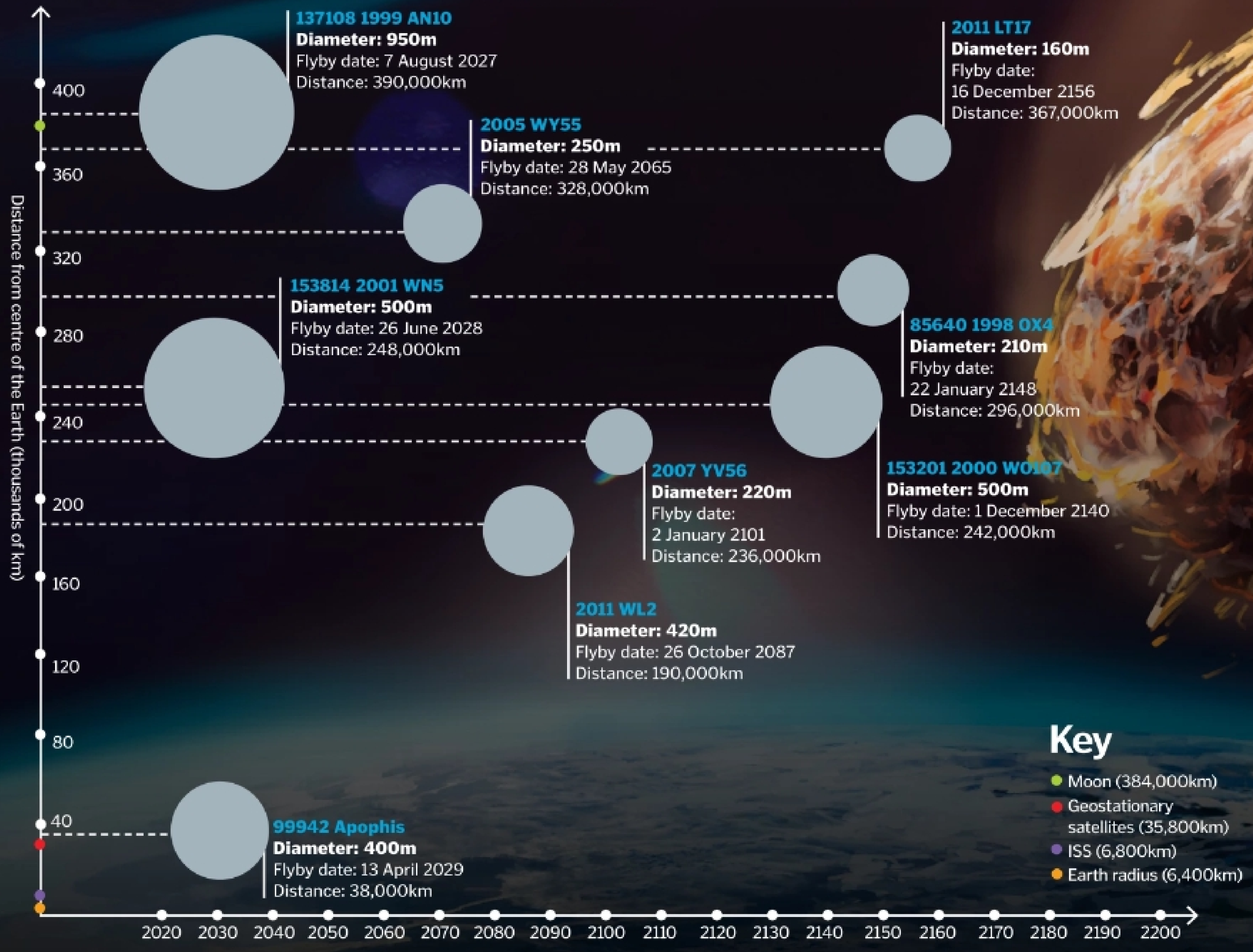
NASA's Near-Earth Object Program detects and tracks asteroids and comets that pose a threat to our planet. The most important part of the programme is identifying Potentially Hazardous Asteroids (PHAs), which could impact Earth in the future. These are classified as asteroids that are over 150 metres wide, on orbits that will bring them within 7.5 million kilometres of us.

Initial estimates of these PHAs often appear threatening because they are based on quite limited observations, which is why the range of distances and flyby dates tend to vary.

These relatively inaccurate predictions are refined over time as more data is collected by NASA's researchers and technology, ultimately providing better figures to draw from. Several weeks after the announcement, NASA updated their predictions for 2013 TX68, which swooped safely past us at a distance of 4 million kilometres. For now, at least, there is nothing for us to worry about.

Potentially Hazardous Asteroids

The space rocks that could come too close for comfort in the next 200 years



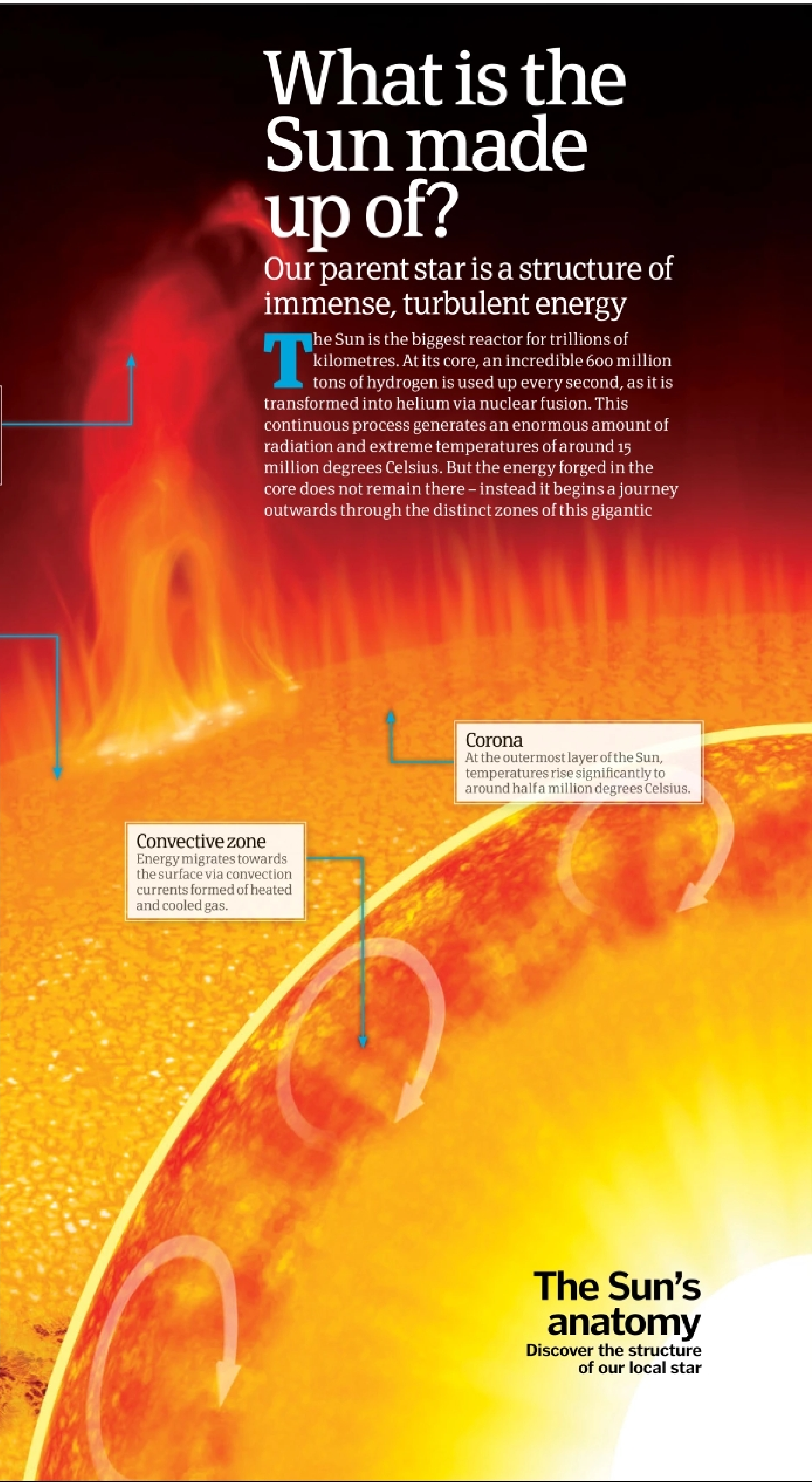
What is the Sun made up of?

Our parent star is a structure of immense, turbulent energy

The Sun is the biggest reactor for trillions of kilometres. At its core, an incredible 600 million tons of hydrogen is used up every second, as it is transformed into helium via nuclear fusion. This continuous process generates an enormous amount of radiation and extreme temperatures of around 15 million degrees Celsius. But the energy forged in the core does not remain there – instead it begins a journey outwards through the distinct zones of this gigantic

The Sun's anatomy

Discover the structure of our local star



Distance from Earth
Our planet orbits at an average distance of 150 million kilometres from the Sun; the right distance for liquid water to exist and for life to flourish.

Flare
Magnetic energy accumulates in the solar atmosphere and eventually explodes from the surface as a solar flare.

Chromosphere
The area directly above the photosphere is actually hotter than the region below it, with temperatures ranging from 3,700 to 7,700 degrees Celsius.

Corona
At the outermost layer of the Sun, temperatures rise significantly to around half a million degrees Celsius.

Convective zone
Energy migrates towards the surface via convection currents formed of heated and cooled gas.

Solar flares

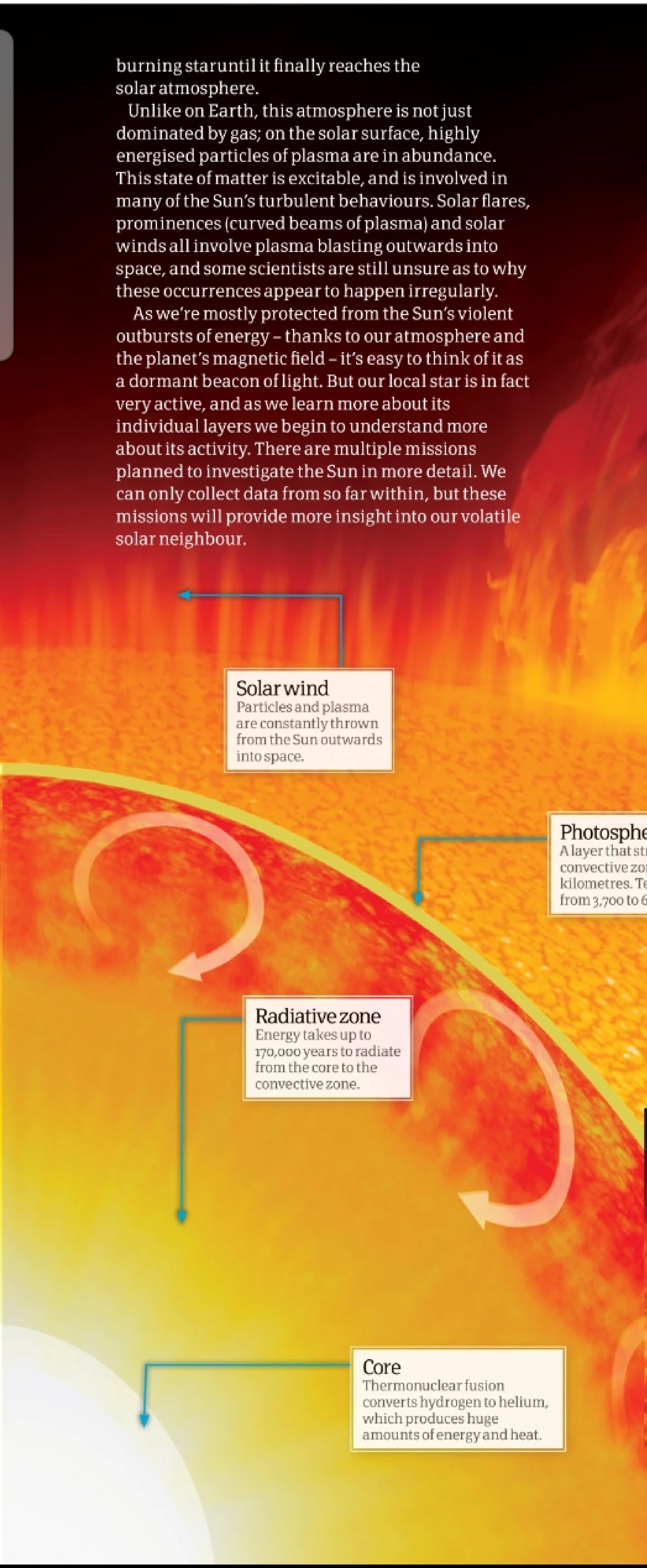
Large solar flares emit truly monumental amounts of energy in the form of radiation. This radiation comes in the form of waves from all across the electromagnetic spectrum, from completely harmless radio waves to very harmful gamma rays.

The amount of energy released in some solar flares is truly breathtaking – it can be roughly equivalent to detonating millions of nuclear bombs at the same time! This incredible burst of energy is the result of heated and accelerated particles in the solar atmosphere, which then move through the outermost layers of the Sun. Here, they cause temperatures to rise up to half a million degrees Celsius and the particles are emitted into space in the form of a flare.

Solar flares release incredible amounts of energy in the form of radiation into the cosmos burning star until it finally reaches the solar atmosphere.

Unlike on Earth, this atmosphere is not just dominated by gas; on the solar surface, highly energised particles of plasma are in abundance. This state of matter is excitable, and is involved in many of the Sun's turbulent behaviours. Solar flares, prominences (curved beams of plasma) and solar winds all involve plasma blasting outwards into space, and some scientists are still unsure as to why these occurrences appear to happen irregularly.

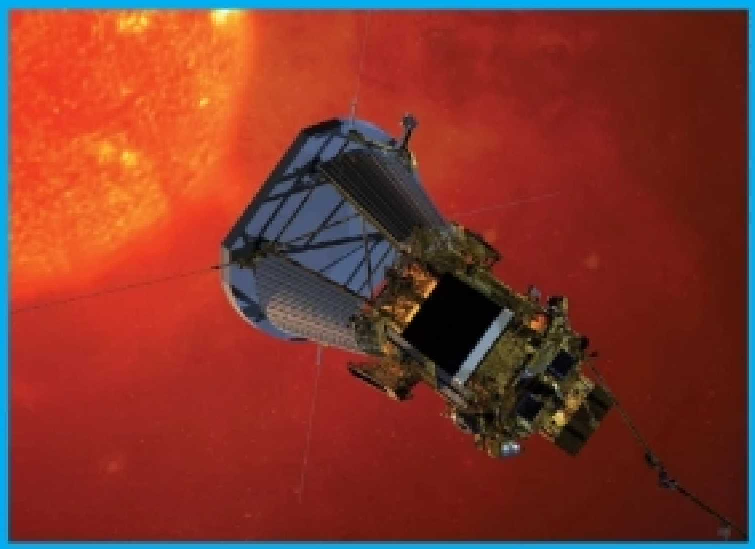
As we're mostly protected from the Sun's violent outbursts of energy – thanks to our atmosphere and the planet's magnetic field – it's easy to think of it as a dormant beacon of light. But our local star is in fact very active, and as we learn more about its individual layers we begin to understand more about its activity. There are multiple missions planned to investigate the Sun in more detail. We can only collect data from so far within, but these missions will provide more insight into our volatile solar neighbour.


Prominence
A huge, curved beam of plasma, anchored to the photosphere, stretches outwards from the surface.
Solar wind
Particles and plasma are constantly thrown from the Sun outwards into space.
Photosphere
A layer that stretches away from the convective zone for about 400 kilometres. Temperatures range from 3,700 to 6,200 degrees Celsius.
Radiative zone
Energy takes up to 170,000 years to radiate from the core to the convective zone.
Core
Thermonuclear fusion converts hydrogen to helium, which produces huge amounts of energy and heat.

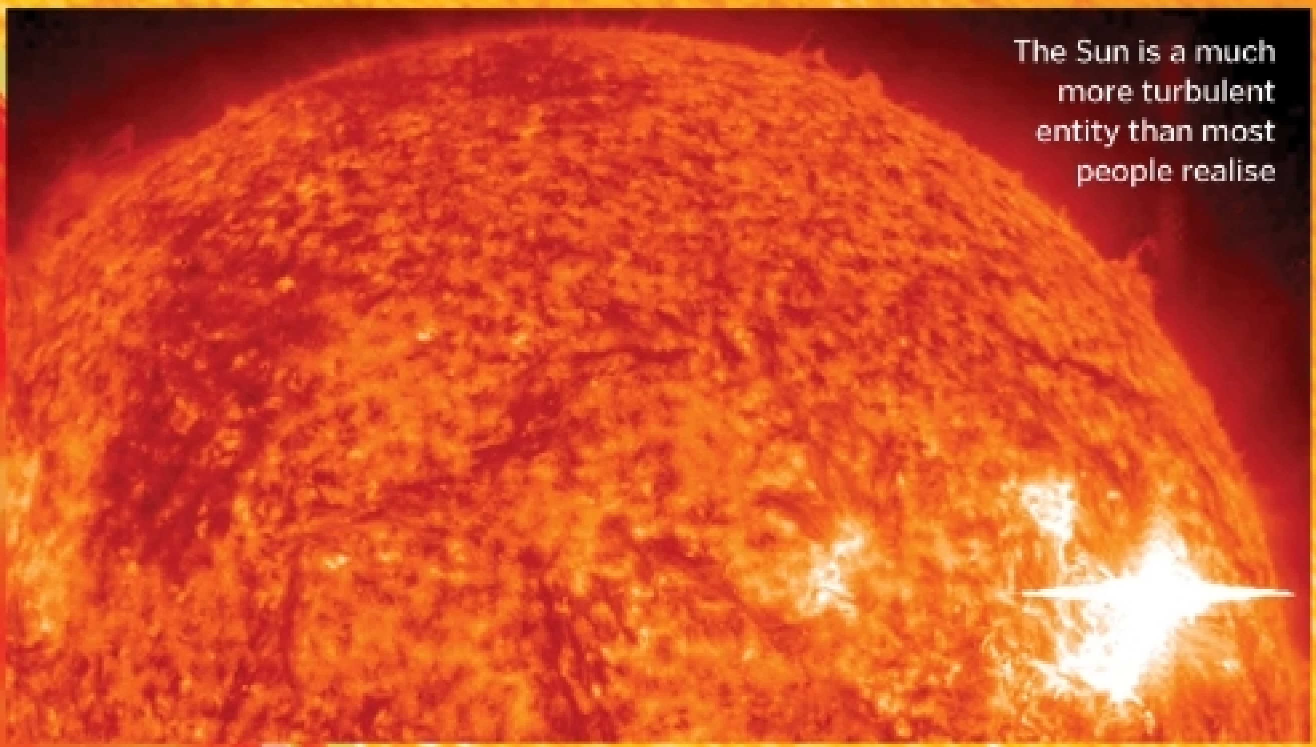
Studying the Sun

Although researchers now know more about the Sun than ever before, it still holds many mysteries. NASA's Solar Probe Plus, currently scheduled for launch in 2018, aims to fly seven-times closer to the Sun's surface than any previous mission in order to collect new data on solar activity.

The probe will have to withstand extreme heat and radiation as it travels within Mercury's orbit, swooping within 6.2 million kilometres of the Sun's surface. To cope with such conditions, the probe will be fitted with an 11.4-centimetre-thick heat shield, enabling it to operate when external temperatures are over 1,300 degrees Celsius. But at least power won't be a concern; at such close proximity, the craft's solar arrays will receive more than enough energy.



The heat shield will keep the Solar Probe Plus' instruments cool enough to function



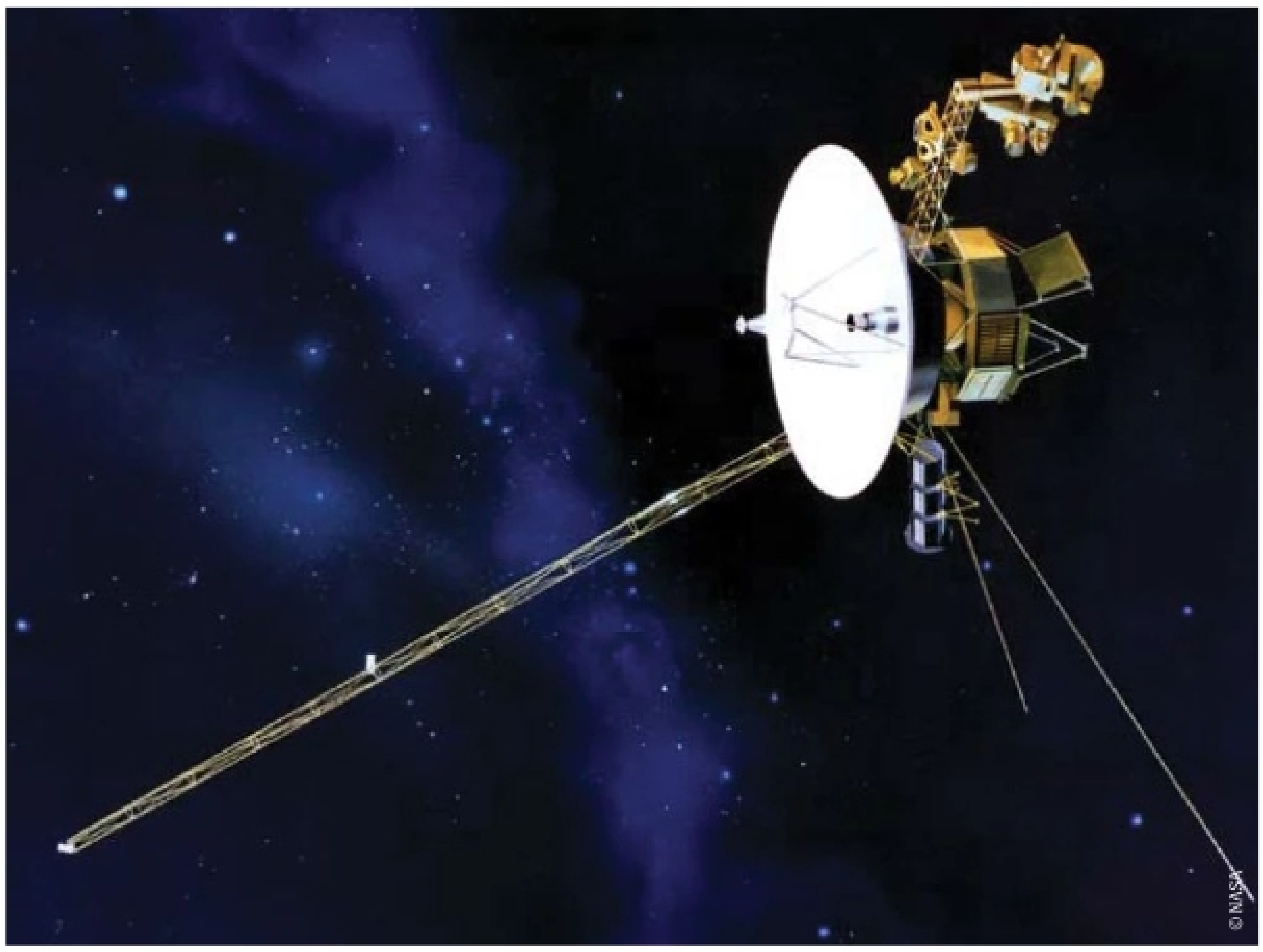
The Sun is a much more turbulent entity than most people realise

© NASA; SPL

> “An apparent solar day varies in length throughout the year by about 16 minutes either side of 24 hours”

Why is a day 24 hours long?

Our 24-hour day is derived from solar time: the time it takes for the Sun to reach the same position on the local meridian (as measured by a sundial, for example). An apparent solar day varies in length throughout the year by about 16 minutes either side of 24 hours, due to our planet's elliptical orbit and tilted axis. However, the average day length is equal to 24 hours, which is what we base our clocks on. This is slightly longer than the time it takes for the Earth to complete a full rotation around its axis: 23 hours, 56 minutes and 4.09 seconds.



© NASA

How far can we send a spacecraft before we lose contact with it?

How far a space probe can go before communication becomes impossible is limited only by the radio technology that we have and will develop.

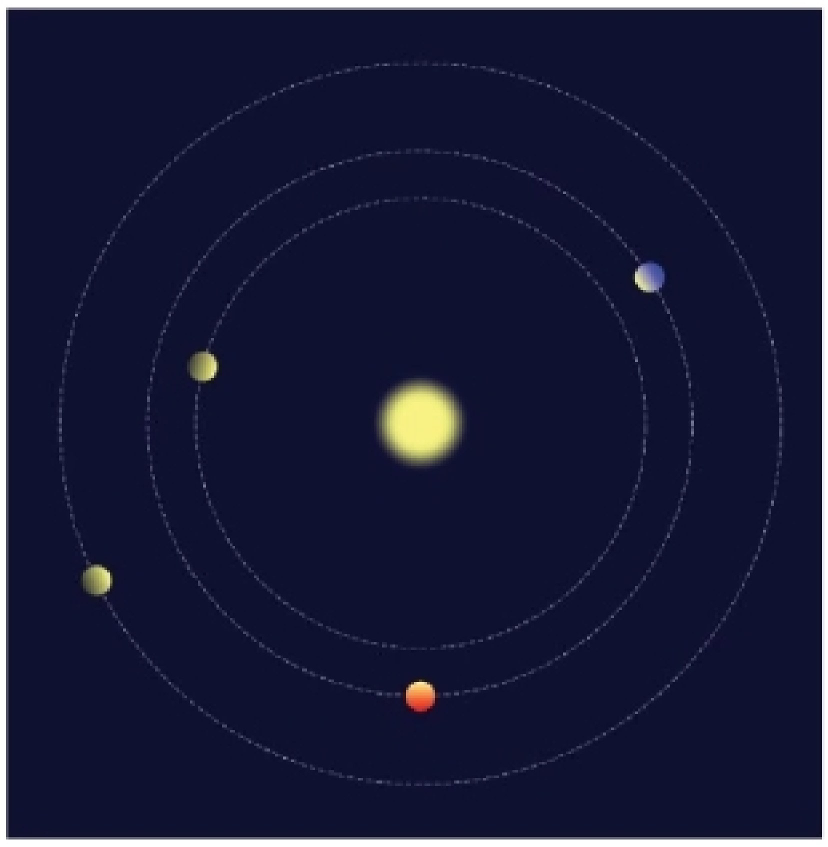
Voyager 1, launched in 1977, is currently over 20 billion kilometres away, but we are still able to exchange information with it using radio signals. On Earth, huge antennae pointed towards the spacecraft pick up its incredibly weak signals, which are then amplified back to us.

Advances in this technology have allowed us to receive transmissions far longer than expected, and newer spacecraft with more powerful transmitters could in theory extend this range even further. We will lose contact with Voyager when it runs out of energy in around 2025.

Can two planets share the same orbit?

Planets can share an orbit, as exemplified by two distant planets in the KOI-730 system spotted by the Kepler Space Telescope. This type of configuration is rare since a shared orbit will usually lead to one planet being flung outwards, or the two colliding.

The only exception is if the larger planet sits in a ‘sweet spot’, 120 degrees in front of or behind the smaller planet. These locations are called Lagrangian points, where the gravitational forces exerted by the other planet and the star cancel each other out, creating a new and relatively stable system.



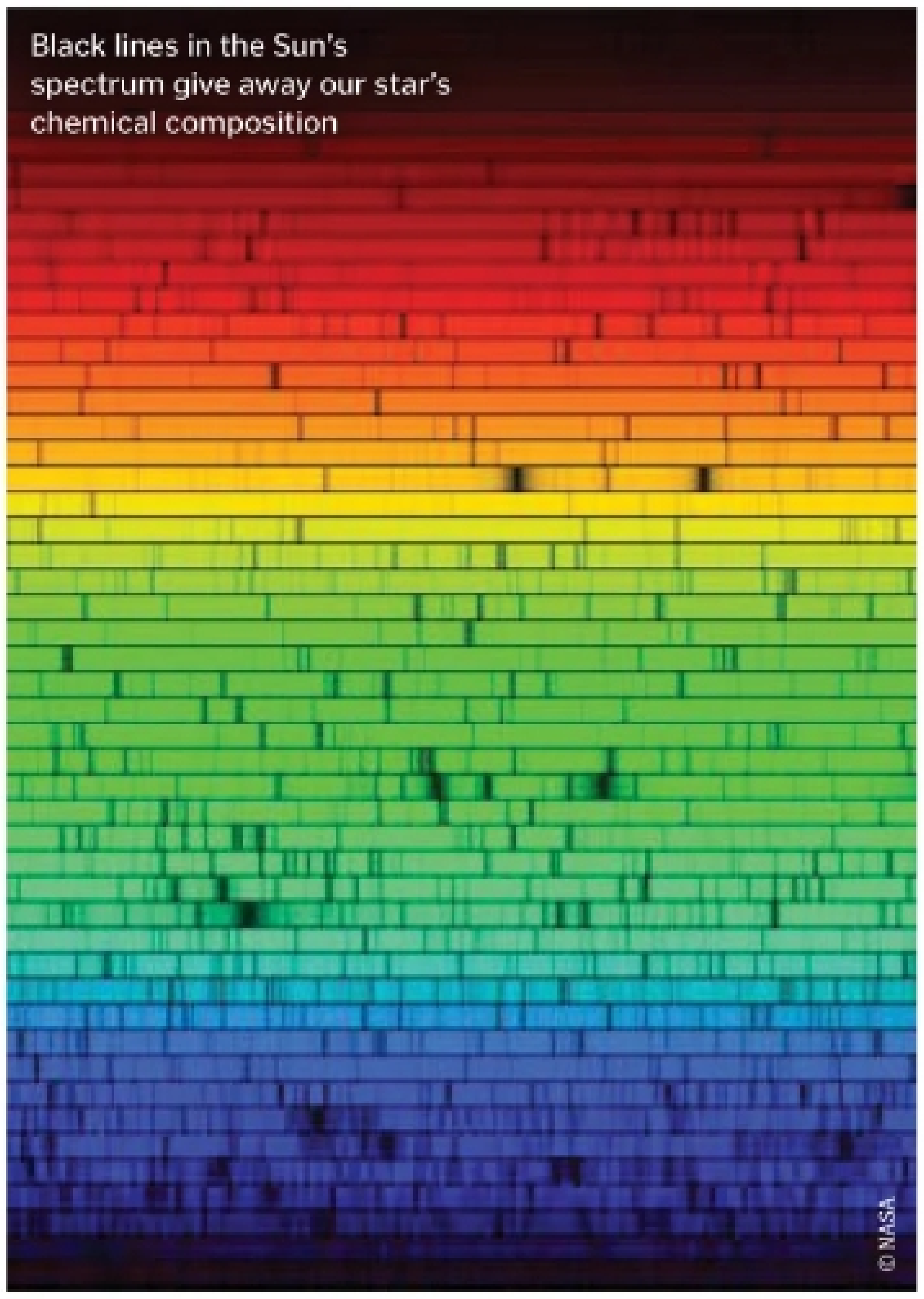
©Luc Viatour

Why is the Moon slowly moving away from us?

The ocean tides are causing the Moon to gradually drift away from Earth. The Moon's gravitational pull on our planet's water creates a slight bulge on the ocean surface on the side of the Earth that is closest. This bulge in turn exerts a gravitational pull on the Moon. But as the Earth rotates, the bulge moves forward in relation to the Moon. As a result, the Earth's rotation slows, giving a little bit of energy to the Moon, making it orbit slightly further away. Each year, the Moon edges about 3.78 centimetres further away.

How do we know what stars are made of?

Astrophysicists learn what stars are made of by studying the light they emit. Light reaching Earth from a star can be analysed using a spectrometer, which separates it out into a spectrum of its constituent colours. However, the spectrum is not a continuous sequence – certain colours of light are absent. This is because elements within the star absorb specific wavelengths. Sodium, for example, absorbs yellow light strongly. By seeing which wavelengths are missing, scientists can deduce which elements make up the star.



Black lines in the Sun's spectrum give away our star's chemical composition

© NASA

> “Light reaching Earth from a star can be analysed using a spectrometer, which separates it out into a spectrum of its constituent colours”

Has all the water on Earth been here since the planet first formed?

Most of the water that we see on Earth today was not around when our planet formed; it was transported onto Earth by comets and asteroids. When the Solar System formed 4.6 billion years ago, water molecules would undoubtedly have been present in the swirling dust and rocks that accreted to form planets. But without an atmosphere, any water on Earth's surface would have vaporised under the high temperature conditions and escaped into space. However, over the next 700 million years, our planet was pummelled with comets and asteroids. These contained ice, which melted into liquid water once they reached Earth's surface.

©NASA

When was the first element discovered?

We have known about elements like gold and silver since ancient times, but the first element to be identified scientifically was phosphorus in 1649. It was discovered by German alchemist Hennig Brand.

> "When the Solar System formed 4.6 billion years ago, water molecules would undoubtedly have been present in the swirling dust and rocks that accreted to form planets"

Why doesn't our Moon have a name?

©NASA

Our moon does have a name: it is called 'Moon' as it was the first moon discovered – all others are named after it.

The word derives from the Old English term 'mona' and was initially used just for our Moon. The term later came to describe other planets' natural satellites in the 17th century, after Galileo famously first observed Jupiter's moons in 1610.

The Moon has other names in other languages: 'Selene' in Greek or 'Luna' in Latin.

Is it possible for a solid to move at light speed?

Einstein's theory of relativity states that it's impossible for an object with mass to travel at the speed of light. Accelerating an object requires energy, and as the speed increases, the amount of energy required to speed it up any further increases. Getting it to the speed of light would require an infinite amount of energy, which is impossible. This is due to the relationship between mass and energy. The faster an object moves (i.e. the more energy it has), the greater its mass.

Despite this, some things can travel at 99 per cent or more of the speed of light. Inside man-made particle accelerators, particles typically travel at speeds just a few metres per second shy of the speed of light.

Science

80 What's harder: brain surgery or rocket science?
86 How do our hearts beat?
88 What is the pH scale?
88 What if we ran out of rare Earth metals?
89 What is the blood-brain barrier?
90 What makes hair curl?
90 Why do our ears pop?
91 What's in a name?
92 What if the magnetic field flipped?
92 How do dogs drink?
93 What are enclosed eco-systems?
94 What if gravity was twice as strong?
94 What are the colours of blood?
95 Is there such a thing as perfect posture?
96 How do hydraulics work?
97 How do nuclear power plants work?
98 Bitesize Q&A

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WHAT'S HARDER: BRAIN SURGERY OR ROCKET SCIENCE?

The two hardest disciplines in science go head-to-head

Both brain surgery and rocket science have reputations for being some of the hardest intellectual fields of work, and those reputations are well earned. The former works with the most complex structure known to man, while the latter wrangles with physics and chemistry to enable the exploration of space.

It's hard to compare the two disciplines directly. Rocket scientists work in the design, development and testing of rocket engines and the vehicles that they propel, whether these are spacecraft, missiles or even jetpacks. Brain surgeons, on the other hand, apply knowledge of neuroscience and anatomy to fix brains that have gone wrong. Rocket scientists do research and development, and their findings allow engineers and mechanics to build and use the big, impressive rockets that carry astronauts to the Moon. Brain surgeons use the science of neuroscientists and tools developed by engineers and physicists to work at the front line of medicine.

A fairer comparison would be rocket scientists versus neuroscientists, or brain surgeons against rocket mechanics, but for the sake of argument, we're going to put this to one side and compare them anyway.

Both fields are relatively new, and are growing in depth and scale all the time as advancements are made. Modern rocket science began in the early 20th century, advanced substantially during World War II with the advent of guided missiles, and leapt out of this world during the space race between the Soviet Union and the United States that began in the 1950s.

Modern brain surgery started at a similar time and has jumped rapidly from crude operations using imprecise tools to precision interventions that take advantage of the latest in biomedical tech. Read on to find out if one really is harder than the other.

Let the battle of the brains begin

It's time to discover the routes and rewards available to these scientists

EDUCATION

Brain surgeon
In the UK, training for brain surgery begins with a five-year medical degree. This is followed by two years of foundation training, and then at least eight more years of neurosurgical training.

Rocket scientist
There are different routes into rocket science, but most begin with a three- or four-year degree. Some follow up with a PhD, but it's possible to enter the field without a university education via an apprenticeship.

RESPONSIBILITY

Brain surgeon
Brain surgeons are responsible for the lives of their patients, and operate on the most complex structure in the human body. Steady hands and millimetre precision are required. This is life and death work.

Rocket scientist
These scientists work on multimillion-pound projects to send the latest tech into space. Most missions are unmanned, but some carry crew. Others work in defence, critical for protecting soldiers and civilians.

SCIENCE

Brain surgeon
The human brain is exquisitely complex, containing an estimated 86 billion neurons. Our understanding of its biology is incomplete, but brain surgeons are effective in their roles regardless.

Rocket scientist
Rocket science is based on physics and formulae, with hundreds of years of research to draw upon. But, rocket scientists work at the edge of this knowledge, combining several scientific disciplines.

ACHIEVEMENTS

Brain surgeon
Brain surgeons have treated hundreds of thousands of people with conditions ranging from brain cancer to epilepsy, changing the lives not only of their patients, but also of their families and friends.

Rocket scientist
Rocket scientists are the brains behind every space mission that has ever launched. Their work took men to the Moon, carried rovers to Mars, and put up every single communications satellite in orbit.

SALARY

Brain surgeon
The starting salary for a newly qualified doctor is about £23,000 a year in the UK, but a consultant surgeon can earn over £100,000. This includes working nights, weekends and on-call.

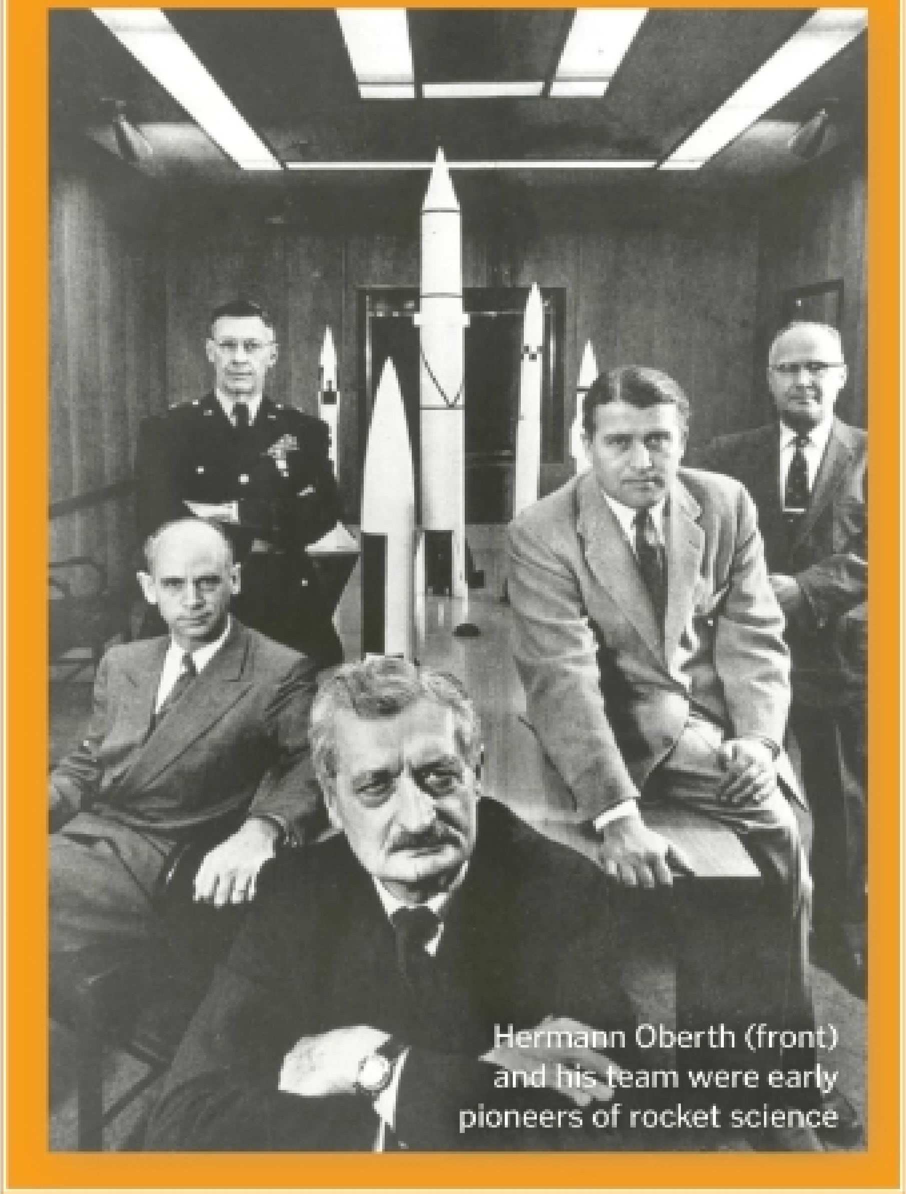
Rocket scientist
The salary for an aerospace engineer starts at around £22,000 in the UK and can rise to over £60,000 with years of experience. The highest paid NASA engineers can earn over $150,000 (more than £120,000).

The defector

Few people can claim to have worked as both a doctor and a rocket scientist, but Hermann Oberth did just that. He was one of the first people ever to work on rocket science, and is hailed by NASA as one of the fathers of rocketry. But before that he was a World War I medic.

His fascination with science began in his early teens, reading Jules Verne science fiction adventure novels while he recovered from scarlet fever. When he returned from the war, he retrained as a physicist and mathematician and started to design rockets. His dream was to escape Earth's gravity, and his books about travel in space, published in the 1920s, cover everything from multi-stage rockets to Moon landings and space stations.

His medical background, combined with a bit of self-experimentation, convinced him that humans could survive a journey out of this world, and after much theorising, his rocket finally launched for real in 1931.


Hermann Oberth (front) and his team were early pioneers of rocket science

Operating while patients are conscious allows surgeons to identify functional areas of the brain that must be avoided

© Alamy, Ryan O'Shea, Thinkstock

Brain surgery

Brain surgeons operate on the most complex structure known to humans

Neurosurgeons are responsible for the treatment of disorders of the brain and spinal cord. It's an area of medicine that has evolved from crude practices like lobotomy to intricate operations performed under microscopes with the assistance of robots.

The field is notoriously complex, and many surgeons choose to specialise in a particular area, including neuro-oncology (tumours), paediatric neurosurgery (babies and children), functional neurosurgery (chronic diseases like epilepsy), neurovascular surgery (aneurysms and blood vessel disorders), or traumatology (head injuries). And surgery only makes up a part of a brain surgeon's week.

They can spend a couple of days in theatre, but the remainder of the time is often spent working with patients outside of the operating room. They attend clinics to diagnose and monitor, and conduct ward rounds to follow up on their patients after they've been operated on.

Many operations typically involve removing a section of the skull and stapling it back into place but, as the field advances, surgeons are working with smaller and smaller incisions. A combination of scans and microscopes help the team to find the correct location during surgery by magnifying brain tissue and revealing areas of damage invisible to the naked eye. And, if the area can't be accessed easily, flexible cameras called endoscopes can be used. These are equipped with surgical tools, allowing surgeons to get at hard-to-reach areas with minimal disruption.

Endoscopes are generally used for surgery at the base of the brain, and the camera is threaded through a coin-sized hole in the skull, or through the mouth or nose. Scans guide the probe, and robotics can be used to steady the camera as biopsies are taken or tumours are carefully removed.

Another option is noninvasive surgery, with a tool called a gamma knife replacing the typical stainless steel scalpels. This process involves the use of beams of gamma radiation to deliver high doses of radiotherapy to specified areas of the brain while sparing as much of the surrounding healthy tissue as possible.

As technology advances, simulation is set to become an invaluable tool in a brain surgeon's arsenal. Computer models will allow doctors of the future to predict the effects of surgery before they do it, taking into account the impact different cuts would have on healing time and side effects. Virtual or augmented reality systems could one day allow surgeons to step inside 3D maps of their patients' brains before, and even during, surgery.

Surgeon Henry Marsh specialises in awake craniotomy procedures, operating on his patients under local anaesthetic

Pioneering practice

Major surgery is most often performed under general anaesthetic, but operating on the brain is a bit different. Keeping patients awake through the procedure can help to protect critical parts of the brain from damage.

At the start of the procedure, the patient is often put to sleep under sedation, allowing a section of the skull to be removed. They are then woken up again. The brain itself doesn't feel any pain, and the scalp is numbed using local anaesthetic.

Using electrical probes, the surgeons stimulate different parts of the brain while the patient reads, talks or even plays an instrument. If there's any change, the surgeons know to avoid that particular area.

Live images enable surgeons to work with pinpoint accuracy

Heroes of brain surgery

Harvey Williams Cushing
Cushing pioneered delicate surgical techniques and performed over 2,000 operations. He gathered samples from every case and created a vast registry, complete with patient notes and photos.

Sir William Macewen
Macewen produced the *Atlas Of Head Sections*, a book that mapped the brain with images of real specimens. He was able to pinpoint damaged areas just by watching for the muscles and senses affected.

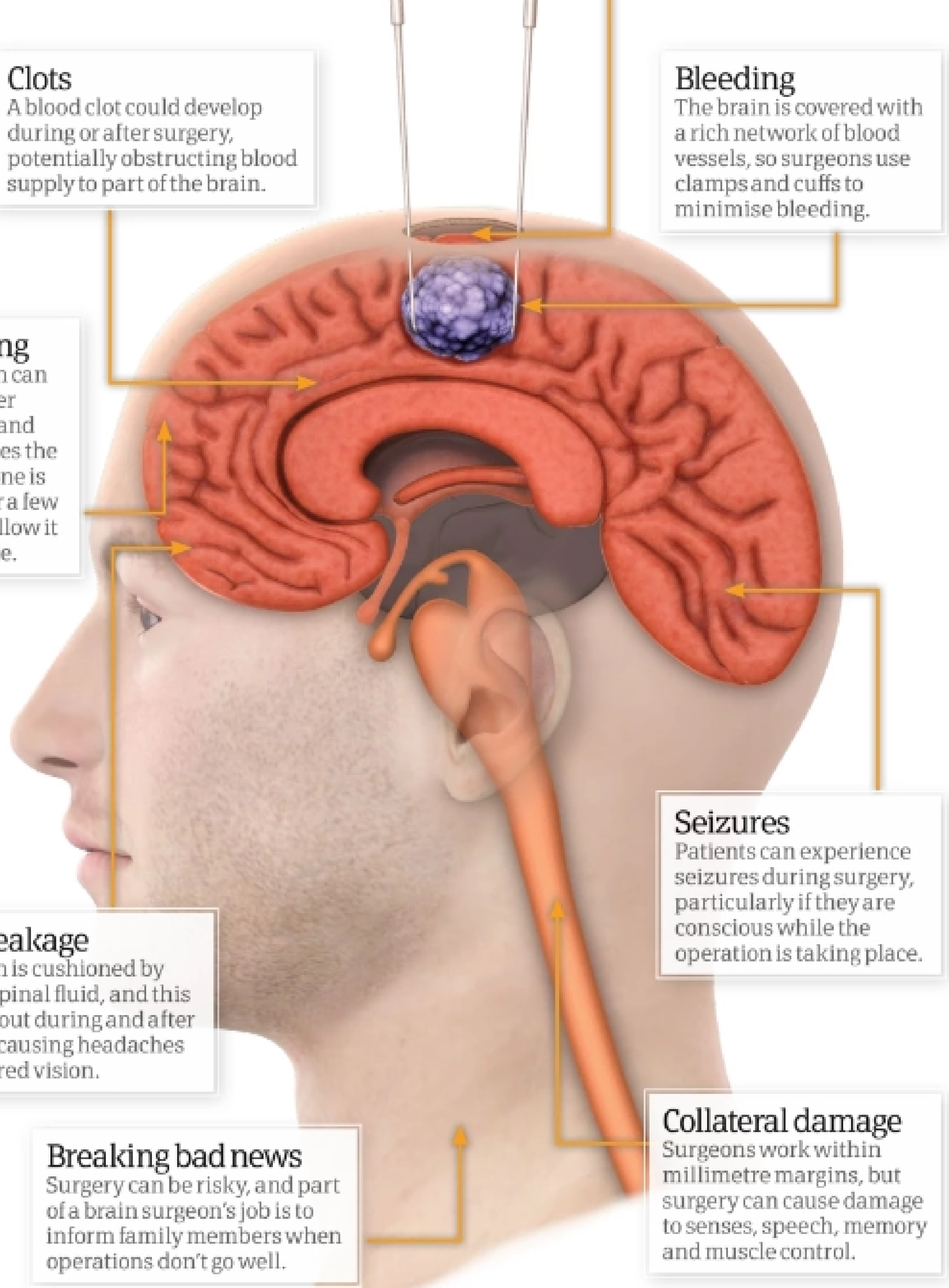
Wilder Penfield
Penfield pioneered 'awake surgery' for patients with epilepsy, keeping them conscious when mapping the areas of the brain responsible for different functions, including speech and memory.

Advanced surgical tools

In brain surgery, the tiniest movements make a difference, so surgeons are turning to robots for help. Endoscopes are already used to perform precision surgery with minimal disruption to surrounding tissue, but tech in development aims to take this even further. Robots are better than human hands when it comes to holding cameras steady, and with their help, laser microscopes should be able to capture high-resolution images inside the brain. Tumour paint is also in development to light up cancer cells. It sticks only to the affected cells, avoiding healthy tissue, and should help to guide surgeons to the parts of the brain that need to be removed.

What makes brain surgery so hard?

There are numerous risks and challenges associated with operating on the brain



Infection
It's critical to keep everything sterile to prevent infection inside the brain.

Clots
A blood clot could develop during or after surgery, potentially obstructing blood supply to part of the brain.

Bleeding
The brain is covered with a rich network of blood vessels, so surgeons use clamps and cuffs to minimise bleeding.

Swelling
The brain can swell after surgery, and sometimes the flap of bone is left off for a few days to allow it to subside.

Seizures
Patients can experience seizures during surgery, particularly if they are conscious while the operation is taking place.

Fluid leakage
The brain is cushioned by cerebrospinal fluid, and this can leak out during and after surgery, causing headaches and blurred vision.

Breaking bad news
Surgery can be risky, and part of a brain surgeon's job is to inform family members when operations don't go well.

Collateral damage
Surgeons work within millimetre margins, but surgery can cause damage to senses, speech, memory and muscle control.

Evolution of brain surgery

Ancient bones suggest brain surgery has a long history

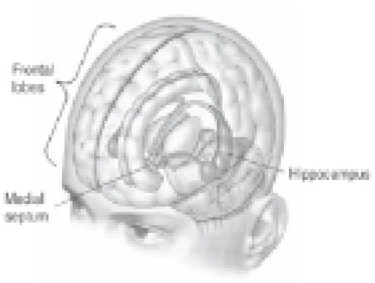
5,000 BCE
Archaeological evidence suggests that the first surgery ever performed was brain surgery. Trepanation involved making a hole in the skull, thought to release spirits and relieve headaches.

1879
In this year, William Macewen removed a brain tumour from a patient for the first time. The woman is thought to have had a slow-growing, noncancerous growth called a meningioma.

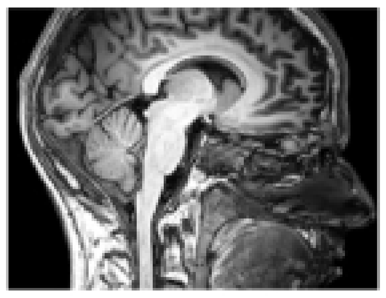
1928
Wilder Penfield began developing the techniques for awake craniotomy, using local anaesthetic to perform brain surgery while patients were conscious, to help avoid damaging functional areas.

1935
The first lobotomy was performed in an attempt to treat mental illness, disrupting connections in the frontal lobes. The practice stopped when drug treatments became available in the 1950s.

1953
A patient known as HM underwent radical surgery to cure his epilepsy, and ended up with severe memory problems. His case was followed for 50 years, revealing a lot about memory.



2017
The first ever human head transplant was attempted by Italian surgeon Professor Sergio Canavero on two cadavers. He used a specially developed knife that cut with micrometre accuracy.



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Rocket science

Rocket scientists design, develop and test rocket engines for use in space and defence

When people think of rocket science, they most often think of space, but the field deals with the physics and engineering of anything powered by rocket engines. This includes missiles, aircraft, spacecraft and, technically, fireworks.

Some of the very earliest rockets were tubes filled with cakes of gunpowder – used by the Chinese as weapons as early as 1132. The powder contains carbon (the fuel), potassium nitrite (the oxidiser) and a bit of sulphur, which helps to get the reaction going. As the gunpowder burns, it creates gas, which shoots out of the back of the tube as exhaust. This exhaust propels the rocket forwards. Adding metal oxides to the mix creates colourful firework displays.

Modern rocketry is based on the same principles, but it didn't really get started until the early 1900s. Rockets contain fuel and an oxidiser and work by funnelling exhaust gas through a nozzle. The nozzle is designed to let the gas expand and cool before it escapes, allowing more energy to be extracted by the engine. The earliest rockets were based on solid fuel, and these are still used to provide powerful, consistent thrust, but the power output can't be controlled or switched off. Newer liquid fuel engines get around this problem, but come with complicated pipe systems and the fuel is heavy and therefore a lot more expensive.

A rocket scientist's job focuses on using expertise across the scientific disciplines to find a balance. Whether it's working out the right combination of rocket stages required to lift a satellite, or developing a new nozzle from lighter materials that can still handle intense heat, they develop, test and refine rocket engines to make them cheaper, safer, lighter, more powerful and more efficient.

To do this, they not only need to understand the chemistry of the propellants; they also need knowledge of engineering, aerodynamics, and the physics of flight. And, with test launches of new technology being expensive and dangerous, much of the development work involves small-scale models and computer simulations. This allows researchers to run multiple tests, tweaking lots of different conditions to come up with the optimal solution before it's ever tested in reality, but it adds an extra layer of complexity to the job.

Advances in rocket engines are going to be crucial as space exploration projects become ever more complex and ambitious, and rocket scientists are the people who are going to make it all happen.

Rockets bring space within reach

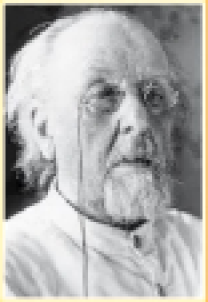
In 1957, the Soviet Union put the first satellite into orbit around the Earth. Known as Sputnik 1, the little metal sphere was the first milestone in a furious race to conquer space.

Four years later, in 1961, Yuri Gagarin became the first person in space. Four years after that, NASA's Mariner 4 visited Mars. After another four years, two people set foot on the Moon in 1969. The pace of progress in this field was astounding, and everything that left the atmosphere did so under rocket power.

By 1971 the Salyut 1 space station was launched, allowing people to remain in orbit around the Earth for weeks at a time. Several others followed, including the legendary Mir, which spent 15 years in service. It was replaced by the International Space Station, a partnership effort between the world's leading space agencies. People have been onboard it continuously since 2000.

Rocket engines also started the two Voyager spacecraft on their journey out of the Solar System in the late 1970s. Both are now further away than Pluto, and Voyager 1 is now in interstellar space. They have sent rovers to Mars, landers to asteroids, and they've launched over 2,000 satellites into Earth-orbit. None of this would have been possible without rocket scientists, and the best is yet to come.

Heroes of rocket science



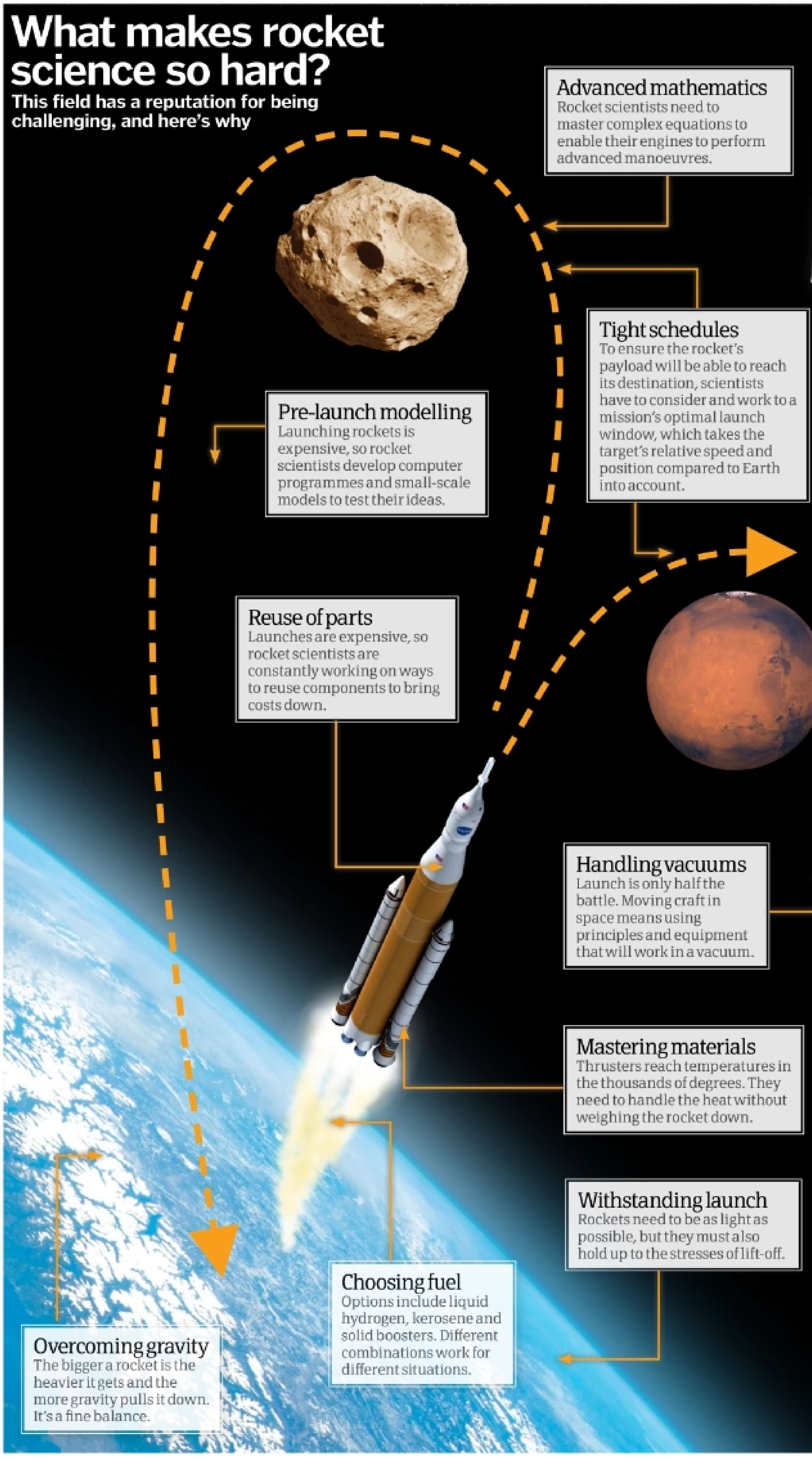
Konstantin Tsiolkovsky
Tsiolkovsky is one of the fathers of rocketry. He published an equation in 1903 explaining the link between a rocket's mass, its speed and the speed of the propellant. It still forms the basis of rocket physics.

Robert Goddard
Goddard made and tested the first liquid fuel rocket in 1926. His ideas revealed the potential for missile and space rocket technology, and his mathematics and testing helped to make them a reality.

Wernher von Braun
Von Braun led the team that developed the German V-2 missile during World War II. After the war, he moved to the US and became chief architect of the Saturn V rocket used for the Apollo missions.

What makes rocket science so hard?

This field has a reputation for being challenging, and here's why



Advanced mathematics
Rocket scientists need to master complex equations to enable their engines to perform advanced manoeuvres.

Pre-launch modelling
Launching rockets is expensive, so rocket scientists develop computer programmes and small-scale models to test their ideas.

Tight schedules
To ensure the rocket's payload will be able to reach its destination, scientists have to consider and work to a mission's optimal launch window, which takes the target's relative speed and position compared to Earth into account.

Reuse of parts
Launches are expensive, so rocket scientists are constantly working on ways to reuse components to bring costs down.

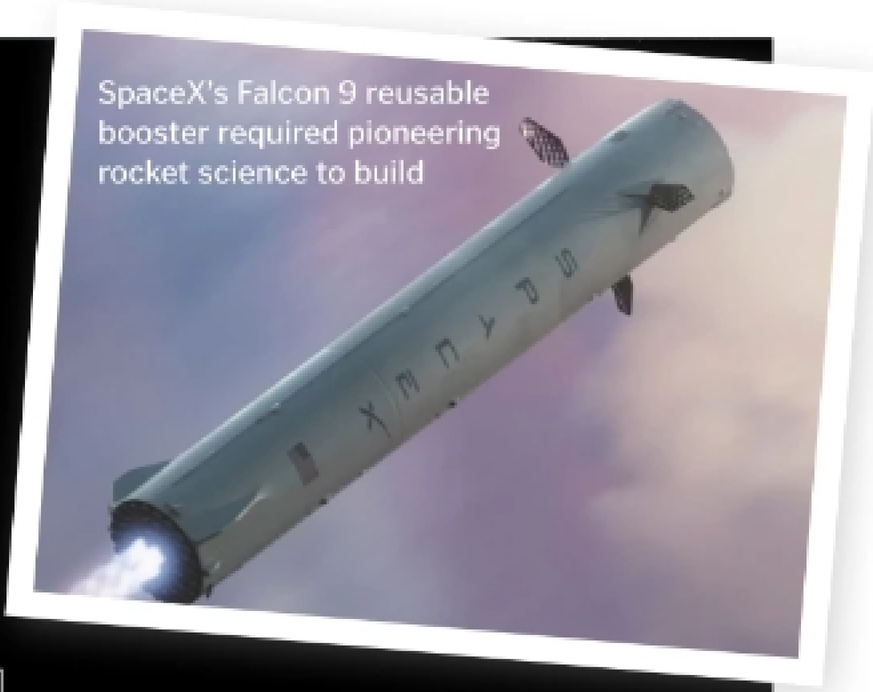
Handling vacuums
Launch is only half the battle. Moving craft in space means using principles and equipment that will work in a vacuum.

Mastering materials
Thrusters reach temperatures in the thousands of degrees. They need to handle the heat without weighing the rocket down.

Withstanding launch
Rockets need to be as light as possible, but they must also hold up to the stresses of lift-off.

Choosing fuel
Options include liquid hydrogen, kerosene and solid boosters. Different combinations work for different situations.

Overcoming gravity
The bigger a rocket is the heavier it gets and the more gravity pulls it down. It's a fine balance.



SpaceX's Falcon 9 reusable booster required pioneering rocket science to build

The verdict?

There's no doubt that both rocket science and brain surgery require some serious thinking power, but it's perhaps unfair that they're singled out as the toughest disciplines in science and medicine. The truth is, none of the achievements made would have been possible without biologists, chemists, physicists, mathematicians and engineers working in other fields.

Rocket scientists build upon decades of scientific enquiry to push the boundaries of human knowledge and develop the technology of tomorrow, while brain surgeons also put research to good use, applying it in the treatment of their patients, often saving lives.

It's safe to say that both are tackling enormous mental challenges, and their work is only going to become more complicated as time goes on.

© NASA; WIKI; SPACEX

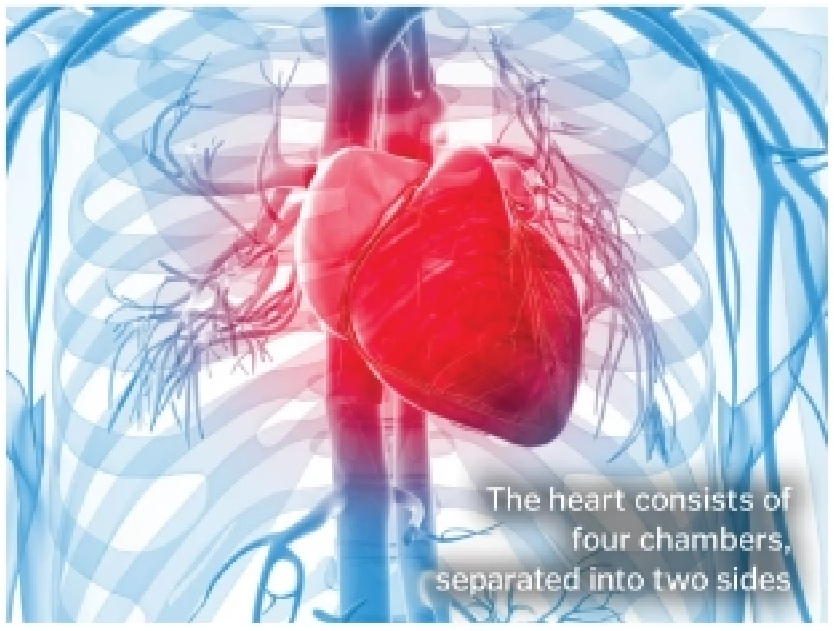
How do our hearts beat?

How one of your hardest-working muscles keeps your blood pumping

Your heart began to beat when you were a four-week-old foetus in the womb. Over the course of the average lifetime, it will beat over 2 billion times.

The heart is composed of four chambers separated into two sides. The right side receives deoxygenated blood from the body, and pumps it towards the lungs, where it picks up oxygen from the air you breathe. The oxygenated blood returns to the left side of the heart, where it is sent through the circulatory system, delivering oxygen and nutrients around the body.

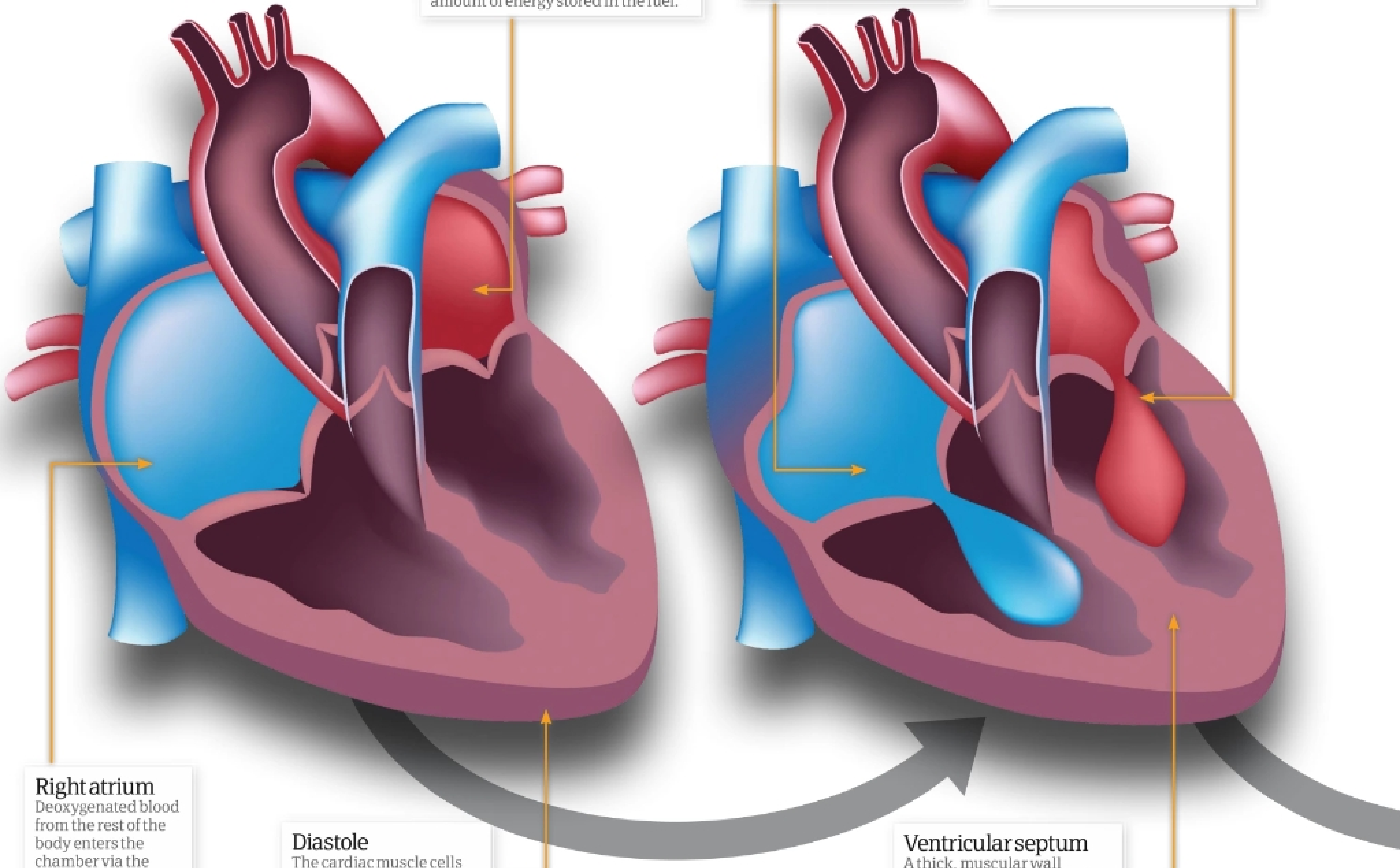
The pumping action of the heart is coordinated by muscular contractions that are generated by electrical currents. These currents regularly trigger cardiac contractions known as systole. The upper chambers, or atria, which receive blood arriving at the heart, contract first. This forces blood to the lower, more muscular chambers, known as ventricles, which then contract to push blood out to the body. Following a brief stage where the heart tissue relaxes, known as diastole, the cycle begins again.



The heart consists of four chambers, separated into two sides

The cardiac cycle

A single heartbeat is a series of organised steps that maximise blood-pumping efficiency



The first law
The amount of kinetic energy and heat energy created is equal to the amount of energy stored in the fuel.

Atrial systole
The atria contract, decreasing in volume and squeezing blood through to the ventricles.

Blood enters the ventricles
The blood moves down into the ventricular chamber due to a difference in pressure.

Right atrium
Deoxygenated blood from the rest of the body enters the chamber via the superior and inferior vena cava.

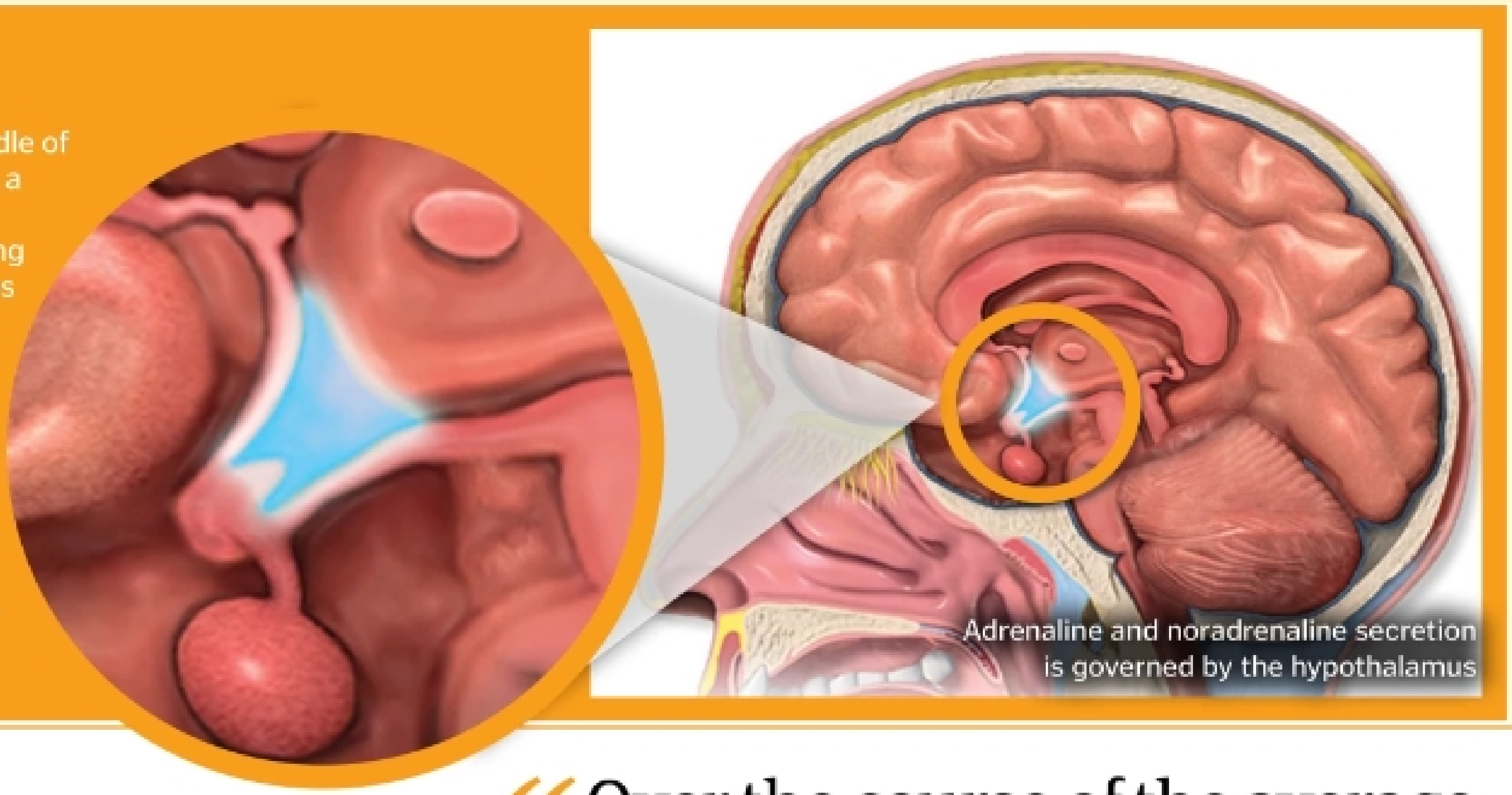
Diastole
The cardiac muscle cells are relaxed, allowing blood to enter the ventricles freely.

Ventricular septum
A thick, muscular wall separates the two ventricular chambers of the heart.

Fight or flight

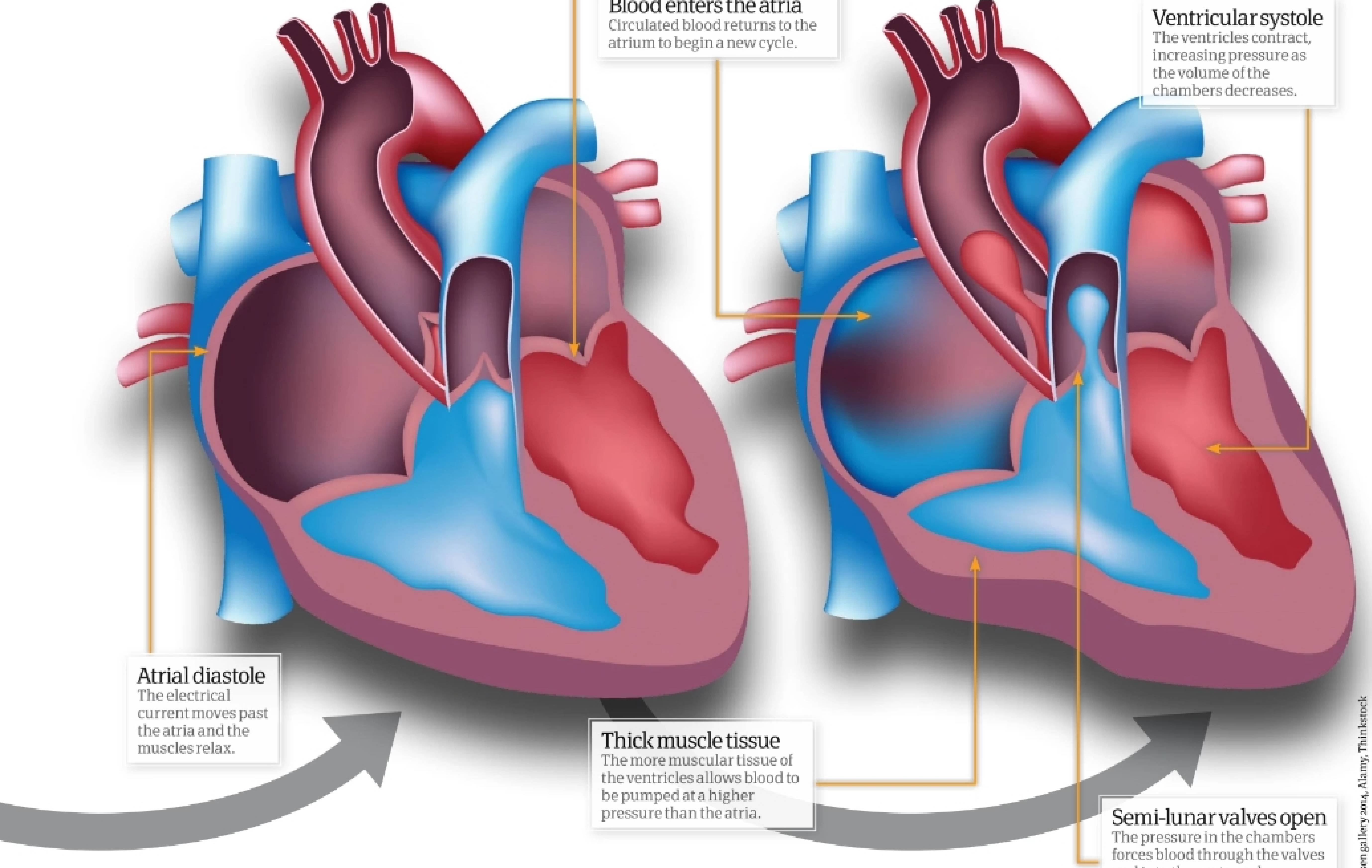
A heartbeat begins at the sinoatrial node, a bundle of specialised cells in the right atrium. This acts as a natural pacemaker by generating an electrical current that moves throughout the heart, causing it to contract. When you are at rest, this happens between 60 to 100 times per minute on average. Under stressful situations however, such as an encounter with a predator, your brain will automatically trigger a 'fight or flight' response.

This results in the release of adrenaline and noradrenaline hormones that change the conductance of the sinoatrial node, increasing heart rate, and so providing the body with more available nutrients to either fight for survival or run for the hills.



Adrenaline and noradrenaline secretion is governed by the hypothalamus

> "Over the course of the average lifetime, the heart will beat over 2 billion times"



Closure of cuspid valves
The valves snap shut to prevent the blood flowing back into the atria.

Blood enters the atria
Circulated blood returns to the atrium to begin a new cycle.

Ventricular systole
The ventricles contract, increasing pressure as the volume of the chambers decreases.

Atrial diastole
The electrical current moves past the atria and the muscles relax.

Thick muscle tissue
The more muscular tissue of the ventricles allows blood to be pumped at a higher pressure than the atria.

Semi-lunar valves open
The pressure in the chambers forces blood through the valves and into the aorta and pulmonary artery.

© Blausen gallery 2014, Alamy, Thinkstock

What is the pH scale?

What do the terms acidic, neutral and alkaline mean?

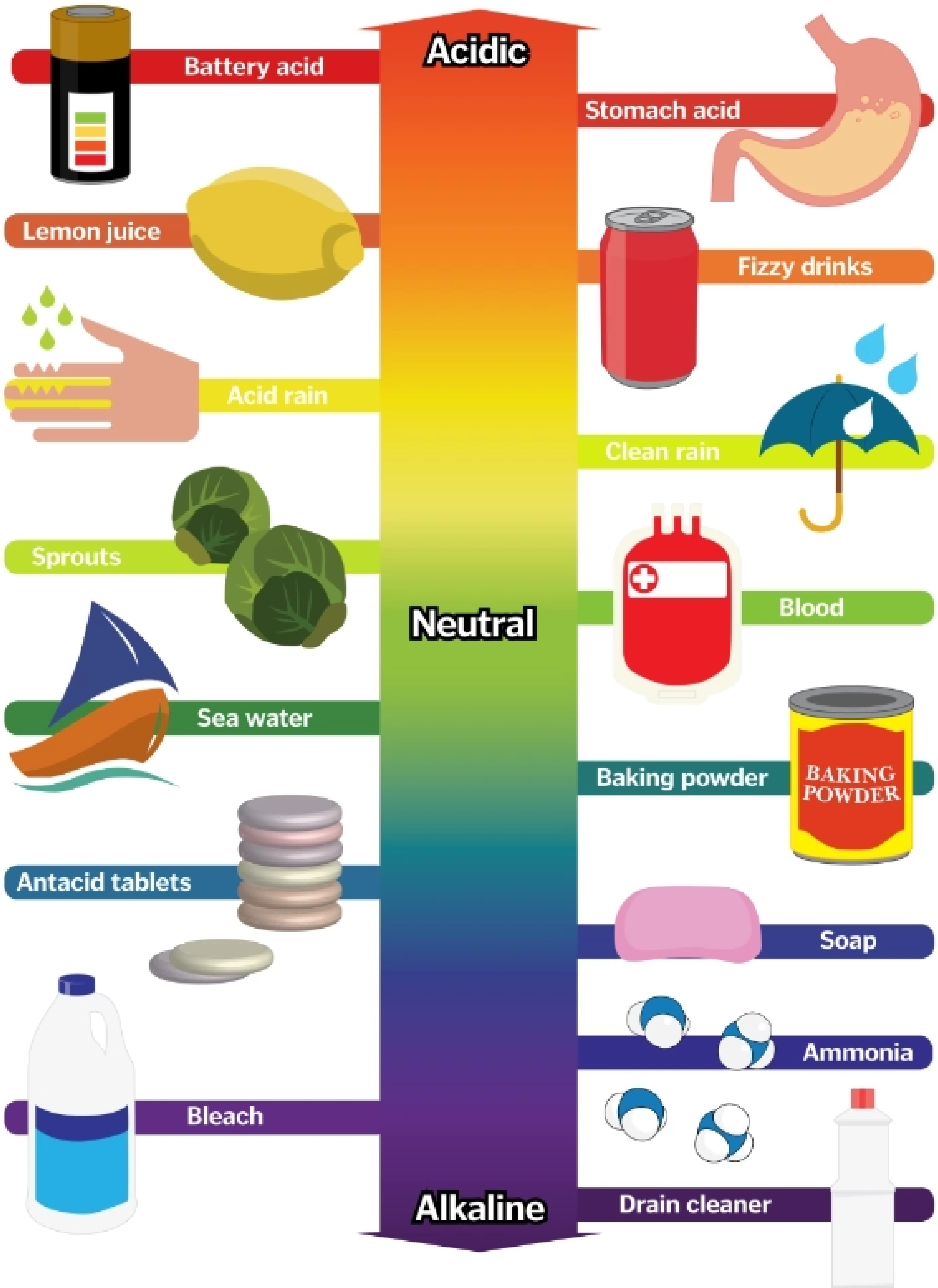
The pH of a solution is a measure of how acidic or alkaline it is on a scale in which 0 is the most acidic, 7 is neutral, and 14 is the most alkaline, but what are we measuring? Let's start in the middle. Pure water has the chemical formula H2O, and is made from two bonded ions: hydrogen and hydroxide. The ions are in pairs, one hydrogen bonded to one hydroxide, and the pH is neutral.

Acids have extra hydrogen ions that do not have hydroxide ions to pair up with, and for every step down in the pH scale, the concentration of these extra ions increases. Solutions of pH 6 have ten times the concentration of hydrogen ions as solutions of pH 7. Solutions of pH 5 have ten times as many again, and so on.

Alkaline solutions have extra hydroxide ions. The concentration increases tenfold with every step up on the pH scale. If you add an acid to an alkali, the extra ions can come together to form water, bringing the pH back towards neutral.

Everyday pH

Find out where everyday substances sit on the pH scale



What if we ran out of rare earth metals?

17 rare earth elements are key ingredients in technology

The rare earth metals behave quite unlike other elements in the periodic table, and they have found their way into smartphones, wind turbines and MRI scanners, to name a few.

They are much more abundant than precious metals like gold, but they are difficult to mine, and we are already running out of good spots to dig. They are bound up with radioactive materials, and extracting them is expensive, dangerous, and damaging to the environment.

Without these elements, the modern world could fall apart. Before we run out of rare earth metals, we are likely to start running out of other vital elements too. Antimony and lead (used for batteries), indium, copper and gold (used in electrical components), and zinc (used to prevent corrosion) are starting to run low.

The most obvious solution is to cut back, to find alternatives, and to recycle the metals that we have already extracted, but there is a fourth option that has sparked the attention of some intrepid explorers: searching in space. NASA, along with private companies like Planetary Resources, have set their sights on near-Earth asteroids, rich in useful elements. If we really did manage to burn through all of Earth's supplies, space mining could be a way to keep our technologies going.

© Rob Lavinsky/iRocks.com

What is the blood-brain barrier?

This biological wall keeps your brain safe and secure

Your brain is arguably your most important organ, and it is vital that it isn't affected by wayward chemicals or aggressive infections. To keep your nerve cells safe, your body builds a biological wall called the blood-brain barrier.

Blood vessels are the highway of the human body, carrying nutrients and oxygen to tissues, and taking away waste products, but unfortunately, they can also transport harmful chemicals and infections. In most parts of the body, chemicals are able to freely cross through the walls of the blood vessels, leaking between the cells and out into the tissues, but thankfully this does not occur in the brain.

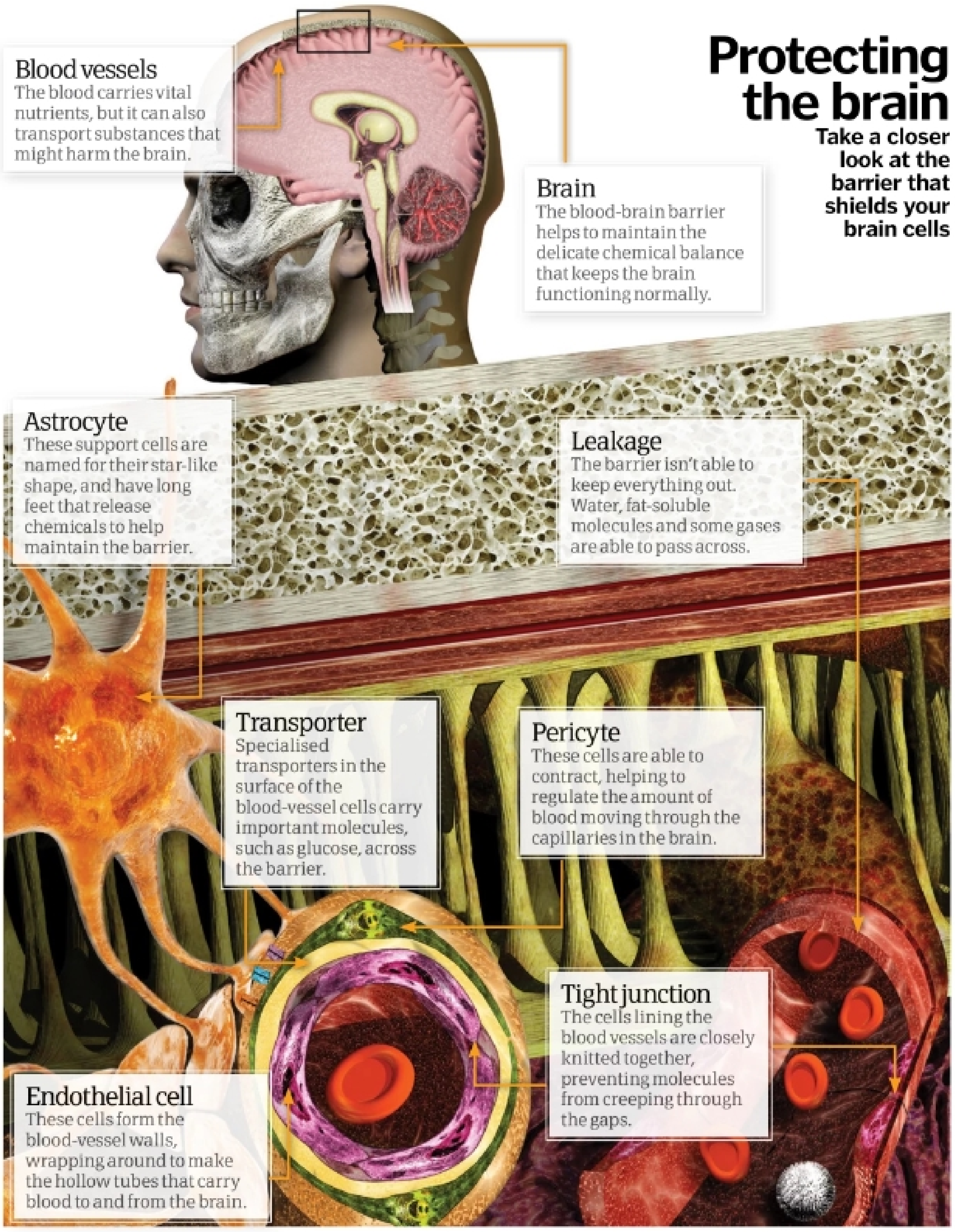
To prevent unwanted contaminants from entering, the cells lining the blood vessels are closely knitted together by structures called 'tight junctions'. Web-like strands pin the membrane of one cell to the membrane of the next, forming a seal that prevents any leakage through the cracks.

Wrapped around these cells are pericytes, which are cells that have the ability to contract like muscle, controlling the amount of blood that passes through the vessels. Just outside the pericytes, a third cell type, the astrocytes, send out long feet that produce chemicals to help maintain the barrier.

Some large molecules, like hormones, do need to get in and out of the brain, and there are areas where the barrier is weaker to allow these to pass through. One such region, called the 'area postrema', is particularly important for sensing toxins. It is also known as the 'vomiting centre', and you can probably guess what happens when that is activated.

Protecting the brain

Take a closer look at the barrier that shields your brain cells



Blood vessels
The blood carries vital nutrients, but it can also transport substances that might harm the brain.

Brain
The blood-brain barrier helps to maintain the delicate chemical balance that keeps the brain functioning normally.

Astrocyte
These support cells are named for their star-like shape, and have long feet that release chemicals to help maintain the barrier.

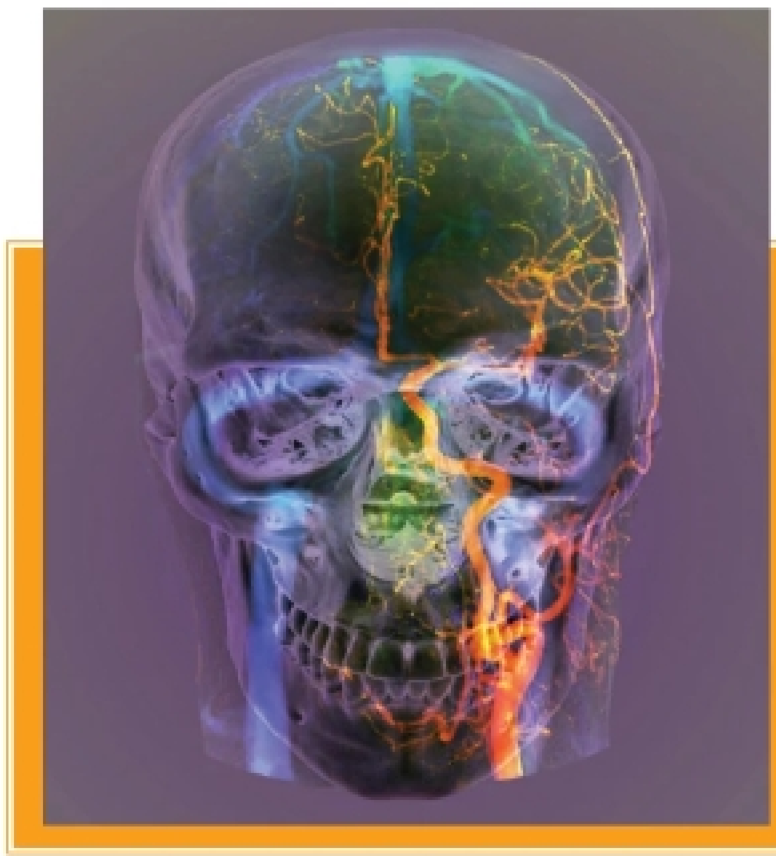
Leakage
The barrier isn't able to keep everything out. Water, fat-soluble molecules and some gases are able to pass across.

Transporter
Specialised transporters in the surface of the blood-vessel cells carry important molecules, such as glucose, across the barrier.

Pericyte
These cells are able to contract, helping to regulate the amount of blood moving through the capillaries in the brain.

Tight junction
The cells lining the blood vessels are closely knitted together, preventing molecules from creeping through the gaps.

Endothelial cell
These cells form the blood-vessel walls, wrapping around to make the hollow tubes that carry blood to and from the brain.



Crossing the barrier

If nothing could cross the blood-brain barrier, your brain cells would quickly die. In fact, water and some gases pass through easily, and the cells are able to take up important molecules, such as sugars, and pass them across. Molecules that dissolve in fat can also slip through, allowing chemicals like nicotine and alcohol to easily pass into the brain. There is a problem, though. Most medicines are too big or too highly charged to cross over, and if a patient has a neurological condition like depression or dementia, treating the brain directly is a real challenge. Researchers are working on ways to breach the barrier, including delivering treatments directly into the fluid around the brain, disrupting the barrier by making the blood vessels leaky, and even designing Trojan horse molecules to sneak treatments across.

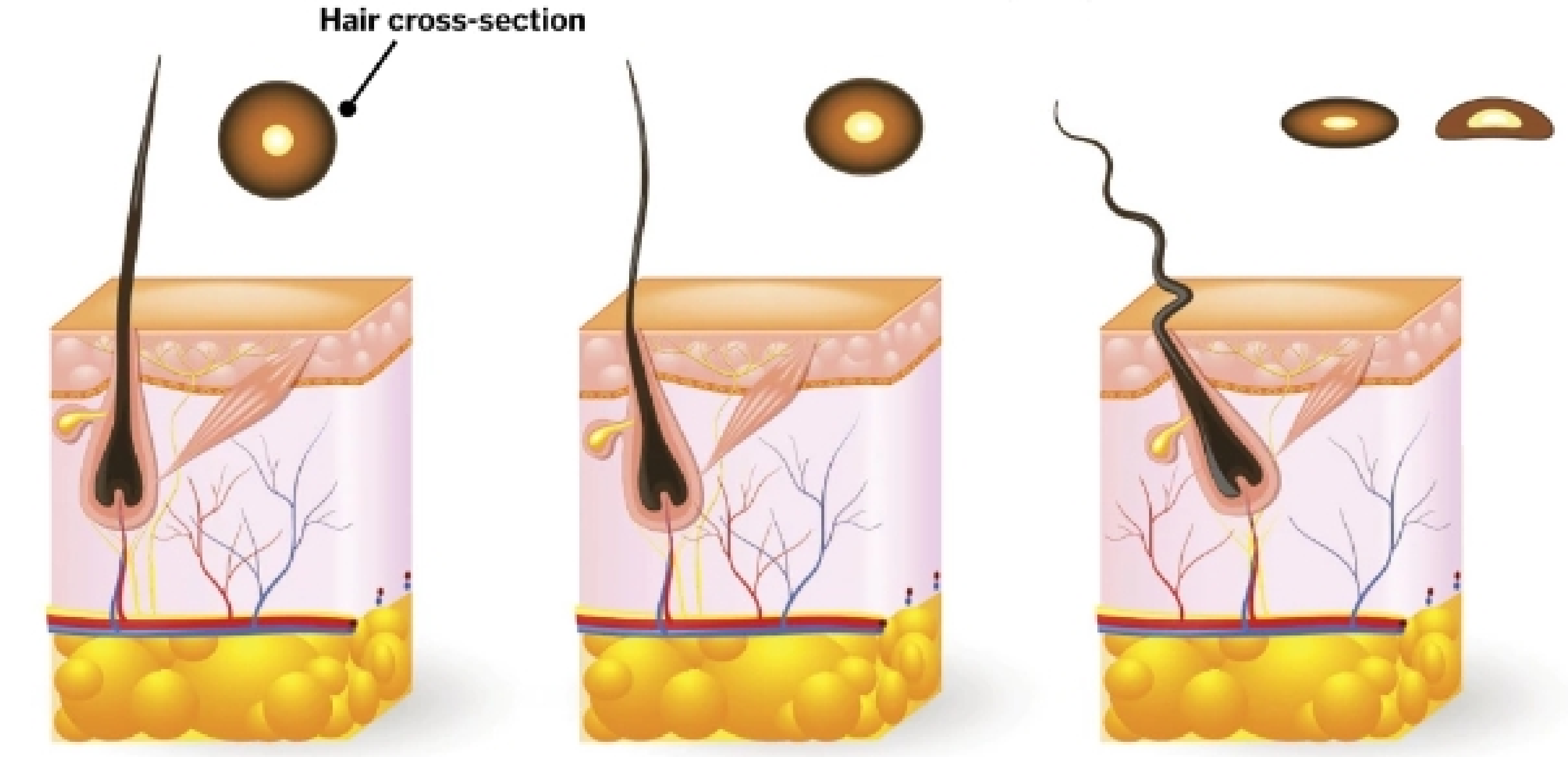
© Science Photo Library, Phototake

What makes hair curl?

The secret to tousled tresses lies under the skin in the shape of the hair follicles

Hairs might look similar from the outside, but put them under the microscope and you'll notice tiny differences in shape. Straight hair is perfectly round in cross section, while curly hair is oval or D-shaped. The strands flex more easily in one direction than the other. If the shape varies along the length of the hair it will tend to twist. If it flips back and forth the hair will crimp or kink. And if the turns are regular it will make waves. These patterns are determined by the hair follicle itself. A look beneath the skin reveals that straight hair follicles are straight and curly hair follicles are S-shaped. In the straight follicles, all the cells work together to make a symmetrical hair, but in curly follicles everything is asymmetrical.

Your hair type depends on the shape of your follicles



Straight hair
Straight hair is circular in cross section and the follicles are straight.

Wavy hair
Wavy hair is slightly flattened and the follicles aren't perfectly straight.

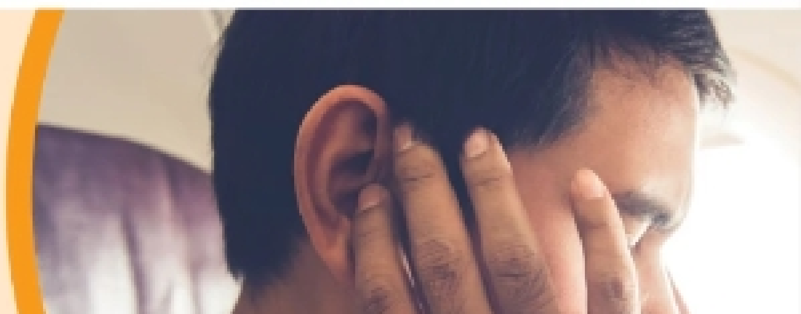
Curly hair
Curly hair is oval or D-shaped and the follicles bend into an S.

Why do our ears pop?

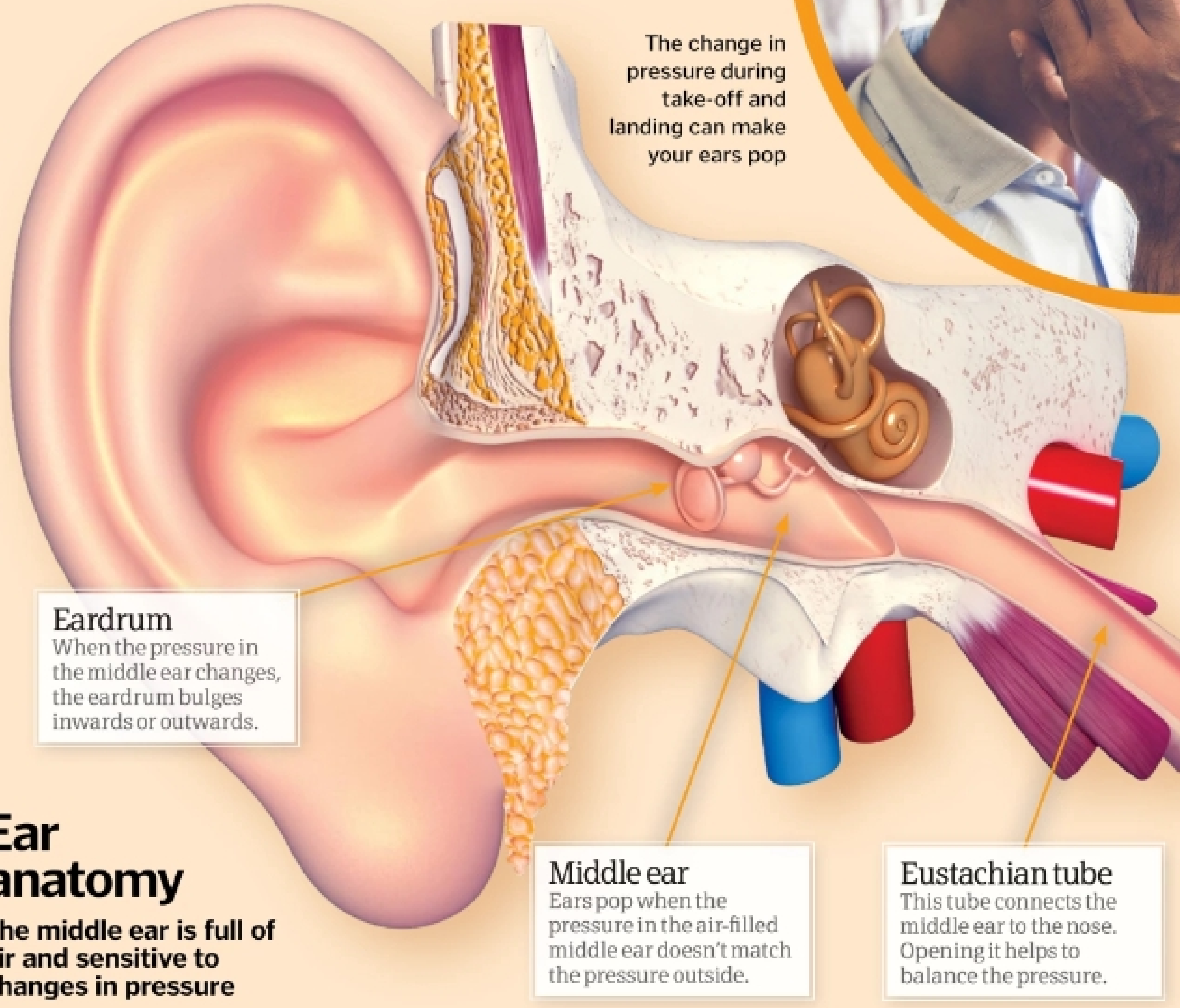
How do changes in pressure make our hearing go funny and our heads feel full?

The middle ear separates the outer ear from the inner ear. It contains the three ear bones, which send vibrations from the eardrum towards the fluid inside the cochlea. The pressure in the middle ear needs to be the same as the pressure in the outside world, otherwise the eardrum can't vibrate properly. Air is constantly leaking out of the middle ear and into the tissues. To keep it topped up the eustachian tube, which runs from the middle ear to the back of the nose, opens and shuts to let air through.

If the pressure changes suddenly, the air inside the middle ear contracts or expands, pushing or pulling on the eardrum. To pop the ears back to normal you just need to open the eustachian tubes to equalise the pressure. Try swallowing, yawning or chewing.



The change in pressure during take-off and landing can make your ears pop



Eardrum
When the pressure in the middle ear changes, the eardrum bulges inwards or outwards.

Middle ear
Ears pop when the pressure in the air-filled middle ear doesn't match the pressure outside.

Eustachian tube
This tube connects the middle ear to the nose. Opening it helps to balance the pressure.

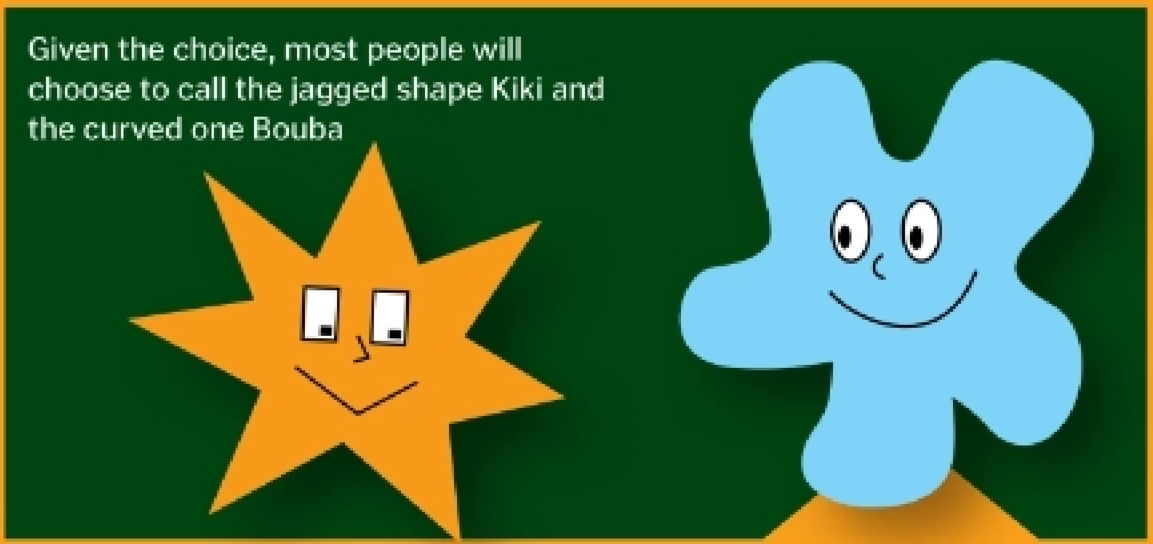
Ear anatomy

The middle ear is full of air and sensitive to changes in pressure

© Getty

What's in a name?

The biology, psychology and sociology of your name may be influencing you more than you realise



Given the choice, most people will choose to call the jagged shape Kiki and the curved one Bouba

Humans have an innate preference for naming shapes

If you look at the characters above, which would you give the name 'Kiki' and which one would you name 'Bouba'? Chances are you answered the same as the majority of other people reading this bookazine.

This is because the brain attaches abstract meanings to shapes, a phenomenon that appears consistent across languages. Scientists think the reason we do this is because the rounded shape our mouth makes when we pronounce Bouba is associated with similar shapes, while we form angular shapes with our mouths when we pronounce Kiki. Research suggests that we associate names like Rose with softer facial features, whereas we might associate Max with more angular features.

It might not be a coincidence if you know a Mrs Read who is a librarian

Usain Bolt set a world record of 9.58 seconds for the 100-metre sprint at the Berlin 2009 World Championships. Even his name sounds fast – Bolt. This isn't the first time we have seen a pattern between a career and an individual's name. Other examples include Sue Yoo, an American lawyer; Dr Michael Docktor of Harvard Medical School; and Scott Speed, a NASCAR racing driver. Researchers think this may be more than humorous coincidence. It's thought that someone's self-image could be determined by their name, or their name might cause expectations among their peers that they take on board. There could also be a genetic explanation; names originating from a career, such as Fisher and Butcher, may be passed on along with the corresponding genes that make their owners suitable for the job.

The theory that names can influence our life choices is called nominative determinism

Those with easily pronounced names are more likely to receive votes in elections and even tend to be higher up within companies

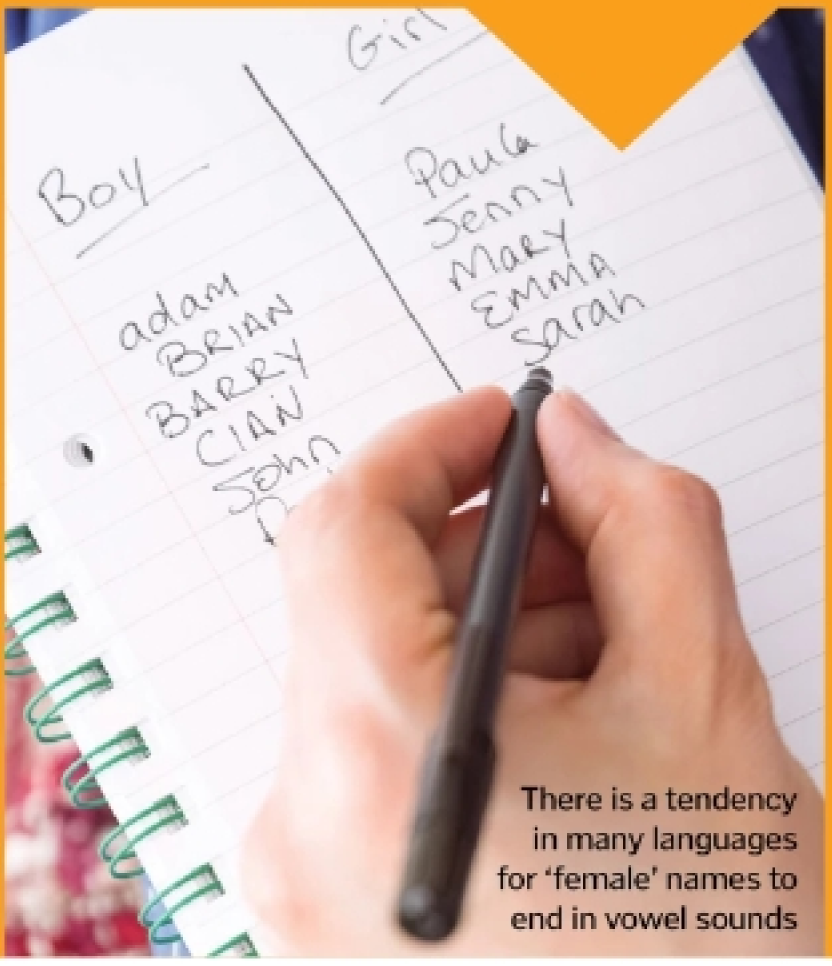
People with easier-to-pronounce names are seen more positively

Experiments that analyse the results of hypothetical elections suggest that we react more positively to names that are easy to pronounce. Studies have also found that lawyers in the US with easy-to-say names tend to hold higher positions. Interestingly, the results were not affected by how familiar a name was to the individual judging the candidate, nor the perceived ethnicity of the surname. This phenomenon stems from the human brain's preference for things we find easy to understand. Reading these names causes feelings of positivity, which means we judge people more kindly. This means surnames such as Evans, Ali or Depp tend to be judged more positively than names like Schwarzenegger, LaBeouf or Cumberbatch, for example.

We say men and women's names differently

Researchers at Columbia University, US, have reported that female and male names are phonetically different. Place your fingers on your throat. Can you feel the difference when you say 'Sophie' compared to 'Thomas'? Male names are generally pronounced as harder-voiced sounds, while female names are softer, unvoiced sounds with less vocal cord vibration.

It's thought that these differences are the result of gender stereotyping.



There is a tendency in many languages for 'female' names to end in vowel sounds

Simply using middle initials can influence how people react to an author's work

Middle initials matter

Dr Wijnand A P van Tilburg and Dr Eric R Igou conducted studies at the University of Limerick to investigate if middle names matter. In a series of experiments students from the university were given extracts from academic texts. Some were given texts written by an author who was listed without a middle name, while others were given pieces penned by an author who had one or more middle names. The latter was interpreted consistently as more prestigious and of a higher standard.

© Getty

What if the magnetic field flipped?

The consequences of compasses pointing south

Earth's magnetic field shields us from solar winds, but north isn't always north. In recent history, the magnetic poles have switched four or five times every million years. It hasn't happened in modern history, so it's hard to know what to expect.

During a flip, the magnetic field weakens and breaks up. This would leave Earth vulnerable to the effects of solar storms, potentially disrupting communications. It could also confuse animals that use magnetic fields to navigate. However, there would be a silver lining. The magnetic field is responsible for the northern and southern lights, and as the poles switched, auroras would become visible across the globe.

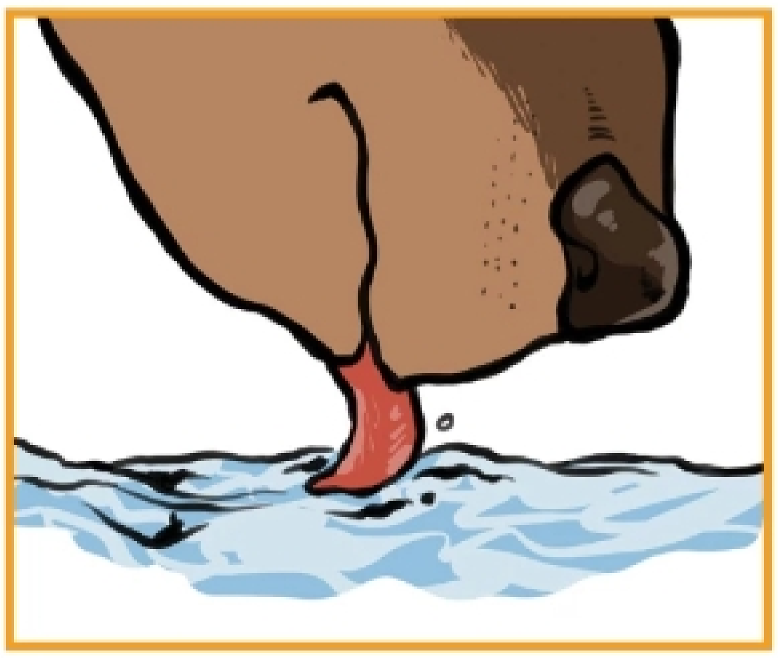
Earth's magnetic field deflects solar winds

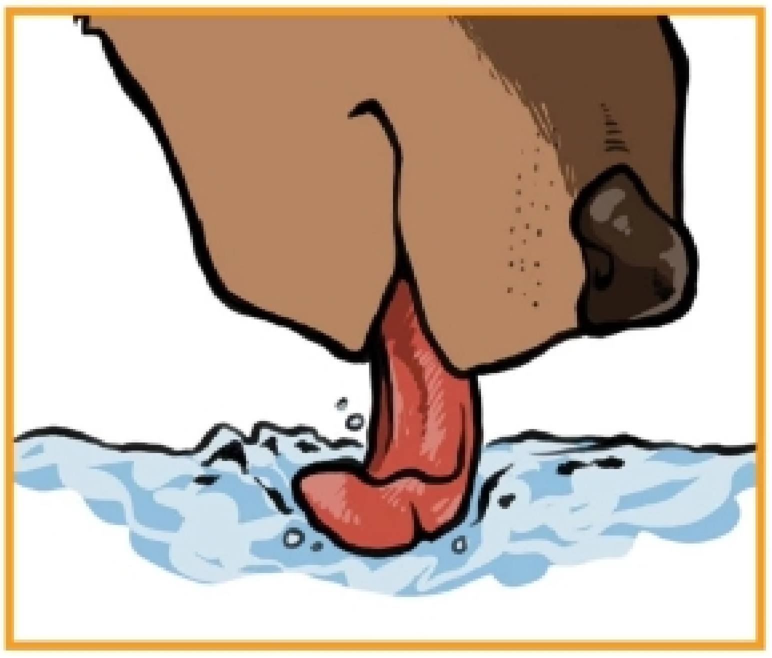
As the poles switch, auroras might become visible across the globe

Dogs use their tongues like scoops to draw water up from the surface

How do dogs drink?

Our clever canine companions use fluid dynamics to quench a thirst

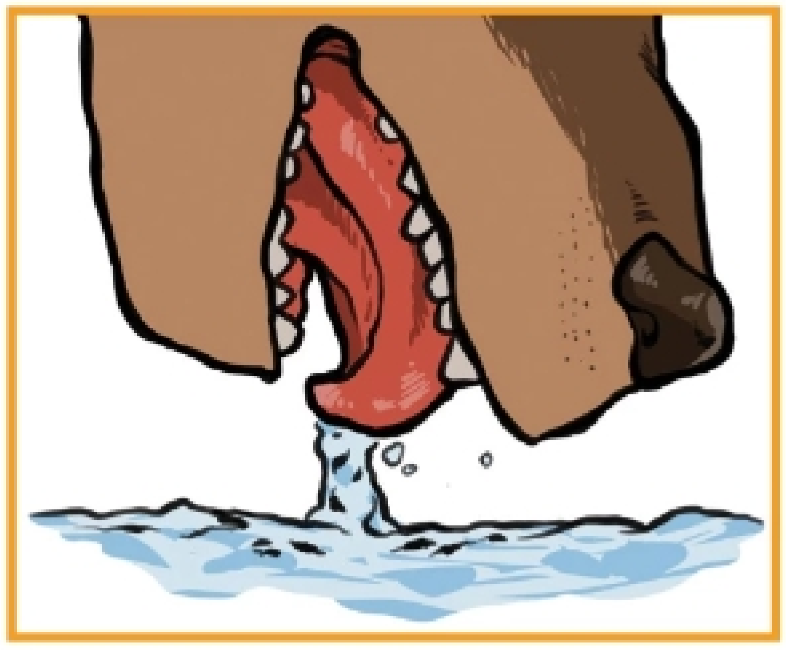


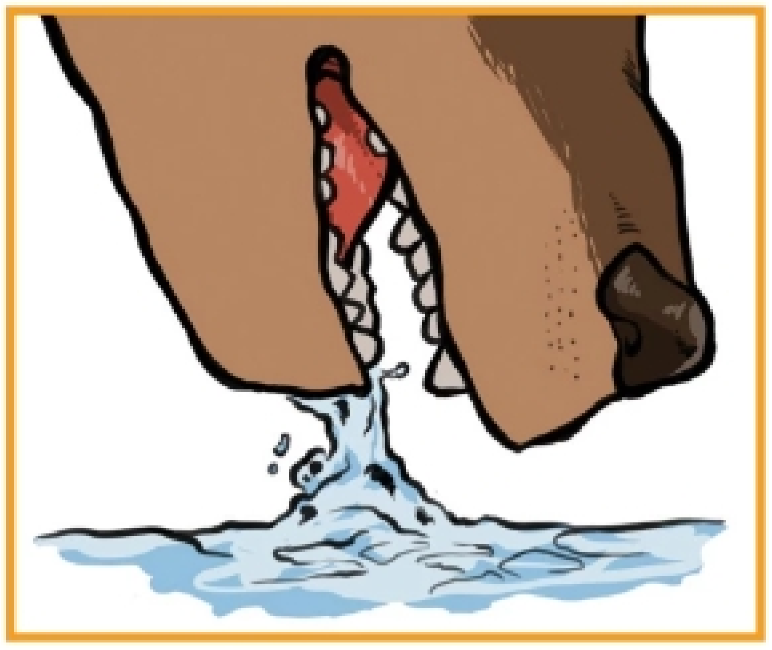


1 Cheeks
Dogs are unable to form a proper seal with their cheeks, so they can't suck up water to drink like we do.

2 Scoop
Using the tip of their tongue like a ladle, dogs scoop up water towards their mouth.

3 Mucky pup
Their tongues don't actually work very well as a scoop. Most of the water falls off as it's retracted.





4 Rapid retraction
Withdrawing the tongue creates a considerable amount of acceleration, as much as five times that of gravity.

5 Water column
This quick, upward motion creates inertia, so the water continues to rise against gravity.

6 Snap shut
Before gravity causes the water column to collapse, the dog closes its mouth around it.

7 Swallow
As the dog scoops up a fresh batch of water, the previous lot is forced to the back of its mouth to be swallowed.

© NASA, Thinkstock

What are enclosed eco-systems?

Having everything you need to survive, all in one small sphere

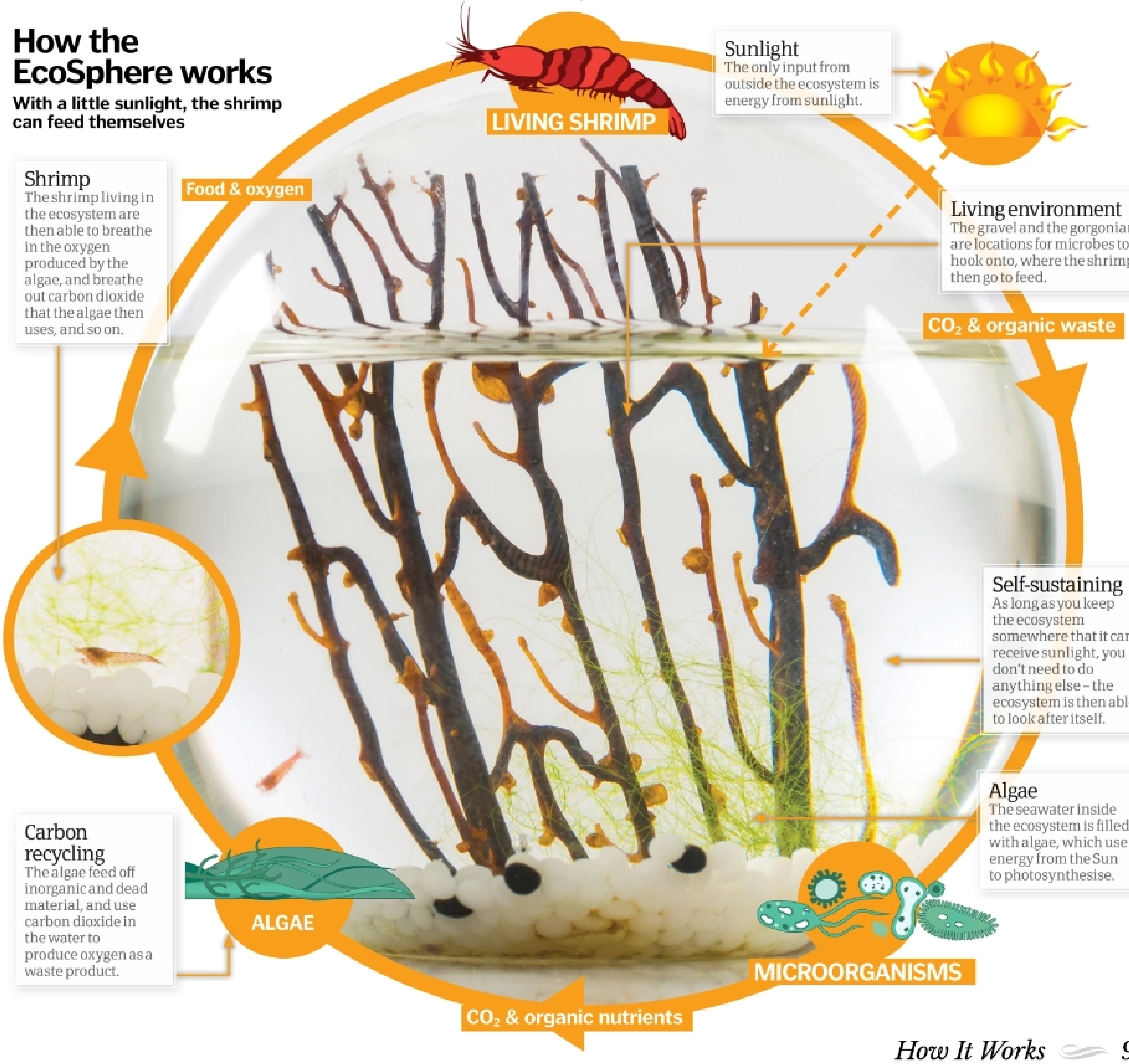
Imagine if you lived in an enclosed sphere with all the resources you need to survive and where the only outside input is sunlight. This is how the three shrimp that arrived in a package from EcoSphere Associates, Inc – a company that builds tiny enclosed ecosystems – not only survive, but thrive. The small glass globe is filled with seawater, algae, microbes, a tree-like gorgonian and gravel.

After receiving a similar globe of shrimp, the famous scientist Carl Sagan said, "Our big world is very like this little one, and we are very like the shrimp…[but] unlike them, we are able to change our environment." If you think about it, the EcoSphere is very much like our own world – everything we need for life is contained on our planet, with only sunlight coming from beyond. The Earth and the shrimp's globe are both enclosed ecosystems where sunlight is turned into energy through photosynthesis, where oxygen and carbon dioxide are recycled and where dead organic matter decomposes and releases nutrients back into the system.

The shrimp breathe oxygen and exhale carbon dioxide, and the carbon dioxide is absorbed by algae to produce oxygen. For the EcoSphere to survive, the cycling of energy, oxygen, carbon dioxide and nutrients must be carefully balanced, and the shrimp must not eat algae faster than it can regrow. Too little sunlight, or using resources faster than they are replenished, could spell disaster for both Earth and the shrimp's world.

How the EcoSphere works

With a little sunlight, the shrimp can feed themselves



Sunlight
The only input from outside the ecosystem is energy from sunlight.

Shrimp
The shrimp living in the ecosystem are then able to breathe in the oxygen produced by the algae, and breathe out carbon dioxide that the algae then uses, and so on.

Living environment
The gravel and the gorgonian are locations for microbes to hook onto, where the shrimp then go to feed.

Self-sustaining
As long as you keep the ecosystem somewhere that it can receive sunlight, you don't need to do anything else – the ecosystem is then able to look after itself.

Carbon recycling
The algae feed off inorganic and dead material, and use carbon dioxide in the water to produce oxygen as a waste product.

Algae
The seawater inside the ecosystem is filled with algae, which use energy from the Sun to photosynthesise.

What if gravity was twice as strong?

Find out if your body could cope under the strain

If gravity had always been stronger, our bodies would have been under pressure to adapt. We might be smaller, with thicker bones and stronger muscles. But we evolved with Earth's gravity as it is, and if it suddenly doubled, we'd be in trouble. Our hearts would struggle to pump against the downward pull, and our bones, muscles and joints would experience serious strain.

Large animals, like elephants, would find high gravity environments extremely challenging

What are the colours of blood?

Animals have evolved some colourful methods of getting oxygen around their bodies

Red

Humans and most other vertebrates

Humans and other vertebrates have red blood thanks to a protein called haemoglobin. Iron atoms in this molecule bind to the oxygen we breathe in order to carry it around the body. This reaction changes the haemoglobin's structure so it absorbs and reflects light differently; oxygenated blood appears bright red while deoxygenated blood is darker.

Green

Marine worms and leeches

Certain species of marine worms and leeches have a molecule called chlorocruorin in their blood. Although this protein is very similar in structure to haemoglobin, it makes their blood green rather than red. Some animals' blood contains a mixture of both chlorocruorin and haemoglobin, so to the naked eye it would appear to be closer to the colour red.

Blue

Octupuses, squid and spiders

Octupuses, squid, crustaceans, spiders and some molluscs have blue blood because it contains a protein called haemocyanin. Unlike haemoglobin (which is bound to red blood cells) haemocyanin flows freely in the vessels, and contains copper atoms rather than iron. Although the oxygenated form of this blood is a shade of blue, it is actually colourless when deoxygenated.

Purple

Marine worms and brachiopods

Some species of marine worms and brachiopods have blood that contains a protein called haemerythrin. This gives it a purple hue when oxygenated. Similar to haemocyanin, haemerythrin is colourless in the absence of oxygen. While this protein contains iron atoms, compared to haemoglobin it isn't suited to binding with oxygen molecules.

© Lyraon, Science Photo Library

Is there such a thing as perfect posture?

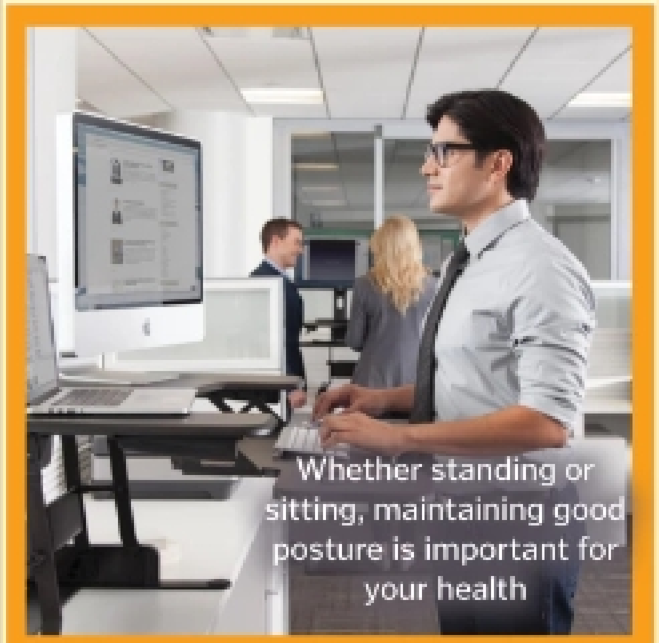
How slouching affects more than just your spine

Chances are most of you reading this aren't sitting or standing properly. Students and office workers know only too well how easy it is to slip into a slouch while spending all day working at a desk. This prolonged poor posture puts stress on the neck, shoulders and spine, contributing to problems such as postural hunchback and spinal misalignment.

Good posture ensures that you can stand, sit or lie down in positions that put the least strain on your body's muscles and ligaments. A quick way to check your posture is to make sure your earlobes are aligned over the middle of your shoulders, your shoulders are in line with your hips, and your hips are directly above your knees and ankles. This correct positioning may take some practice, but as you retrain your muscles it becomes second nature.

In addition to putting stress on your bones and muscles, bad posture affects how efficiently we breathe. Hunching the shoulders restricts the amount by which the ribcage can expand, reducing lung capacity by as much as 30 per cent. Poor posture has also been linked to neurological issues and heart disease.

A surprising side effect of posture is that it can change how people think. A study by Ohio State University in the US found that people who sat up straight exhibited a more confident and positive outlook than those who slumped over.

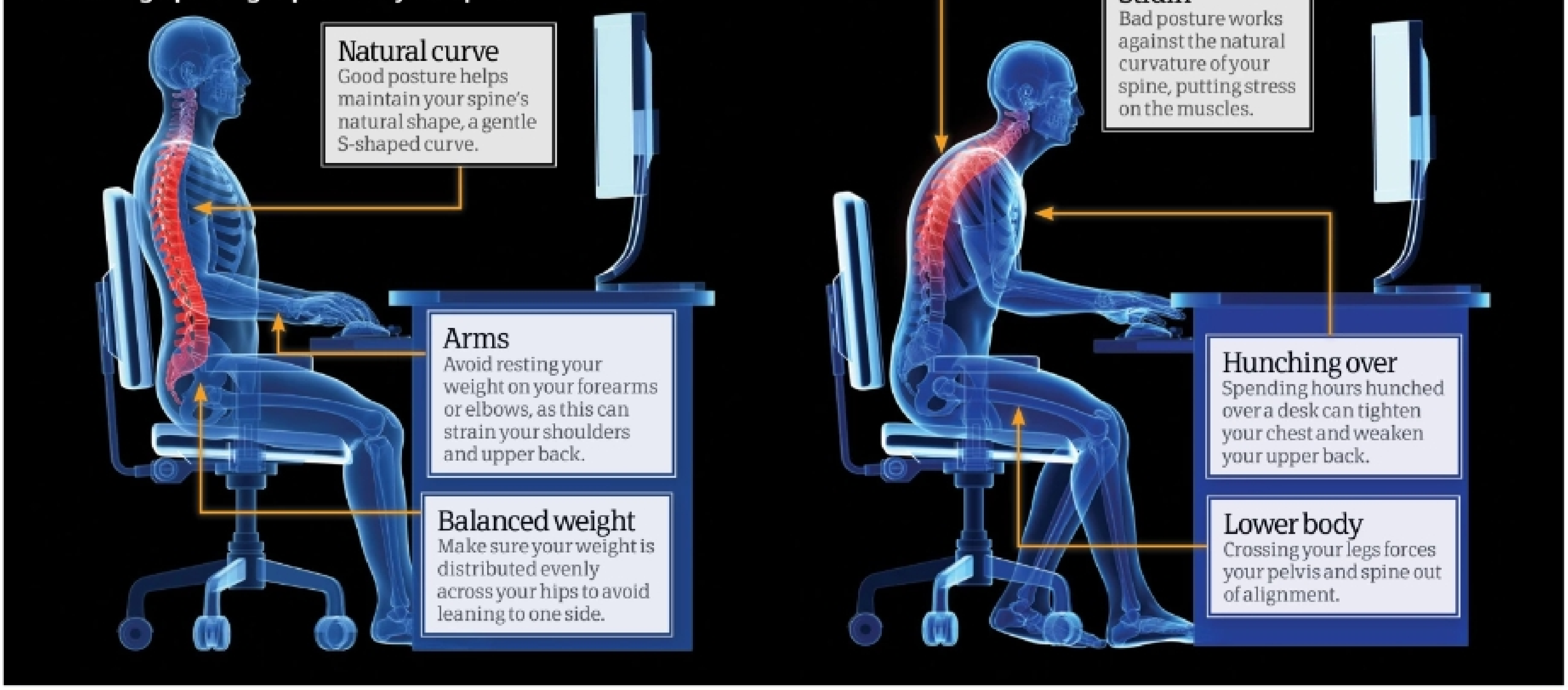

Whether standing or sitting, maintaining good posture is important for your health

Sit-stand desks

With some research highlighting the negative health effects of sedentary lifestyles, sit-stand desks like the VARIDESK are becoming much more popular in office and home spaces. These adjustable platforms make it easier to alternate between sitting and standing throughout the day, to avoid staying fixed in the same position for hours at a time. Find out more at www.varidesk.com.

Seated posture

How sitting up straight protects your spine



Natural curve
Good posture helps maintain your spine's natural shape, a gentle S-shaped curve.

Arms
Avoid resting your weight on your forearms or elbows, as this can strain your shoulders and upper back.

Balanced weight
Make sure your weight is distributed evenly across your hips to avoid leaning to one side.

Strain
Bad posture works against the natural curvature of your spine, putting stress on the muscles.

Hunching over
Spending hours hunched over a desk can tighten your chest and weaken your upper back.

Lower body
Crossing your legs forces your pelvis and spine out of alignment.

Breaking bad habits

Most of us are guilty of these common posture mistakes, but luckily they can be corrected

Slouching

Reclining with no lower back support can feel comfortable as it requires less muscular effort, but over time this puts pressure on some muscles while weakening others.

'Donald Duck' posture

Frequently wearing high heels or being pregnant can pitch your weight forward, so your upper body leans forward of your hips and your bottom sticks out.

Jutting chin

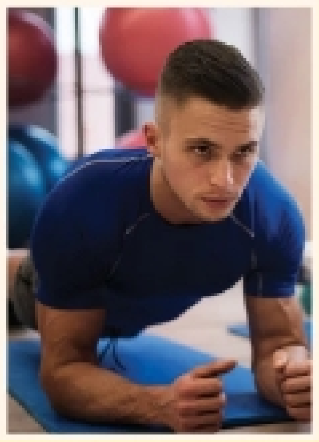
Poking your chin out when viewing a screen is a by-product of poor posture. Hunched shoulders angle the neck and head down, so the chin is lifted to keep looking forward.

Standing on one leg

Leaning on one leg, rather than having your weight evenly distributed between both of them, puts extra pressure on one side of your lower back and hips.

The solution

Practise makes perfect! Consciously correcting your posture will help improve it over time. Strengthening your core with exercises like back extensions and planks will also help re-train weakened muscles.



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How do hydraulics work?

The science behind using liquid power to do heavy lifting

Hydraulics are used to perform heavy industrial work

Hydraulics is the system of using liquids to produce power. Liquids can't easily be compressed, so pushing on them transmits pressure through them. The pressure is evenly transferred through the liquid, so a small push can be used to create a large force elsewhere. This can be used to move pistons, which in turn can be used to perform work, such as lifting with a crane or braking a car.

Gases can be squashed, pushing the molecules closer together to fit into a smaller space, but liquids are hard to compress, as the molecules are close already. Particles bump around as they move, generating pressure. Push on a liquid, and pressure is increased.

In a container with two cylinders and two pistons, connected by a fluid, when you push down on a piston in the first cylinder, it will push a piston up in the second. The pressure is equal to the force applied, divided by the cross-sectional area of the piston.

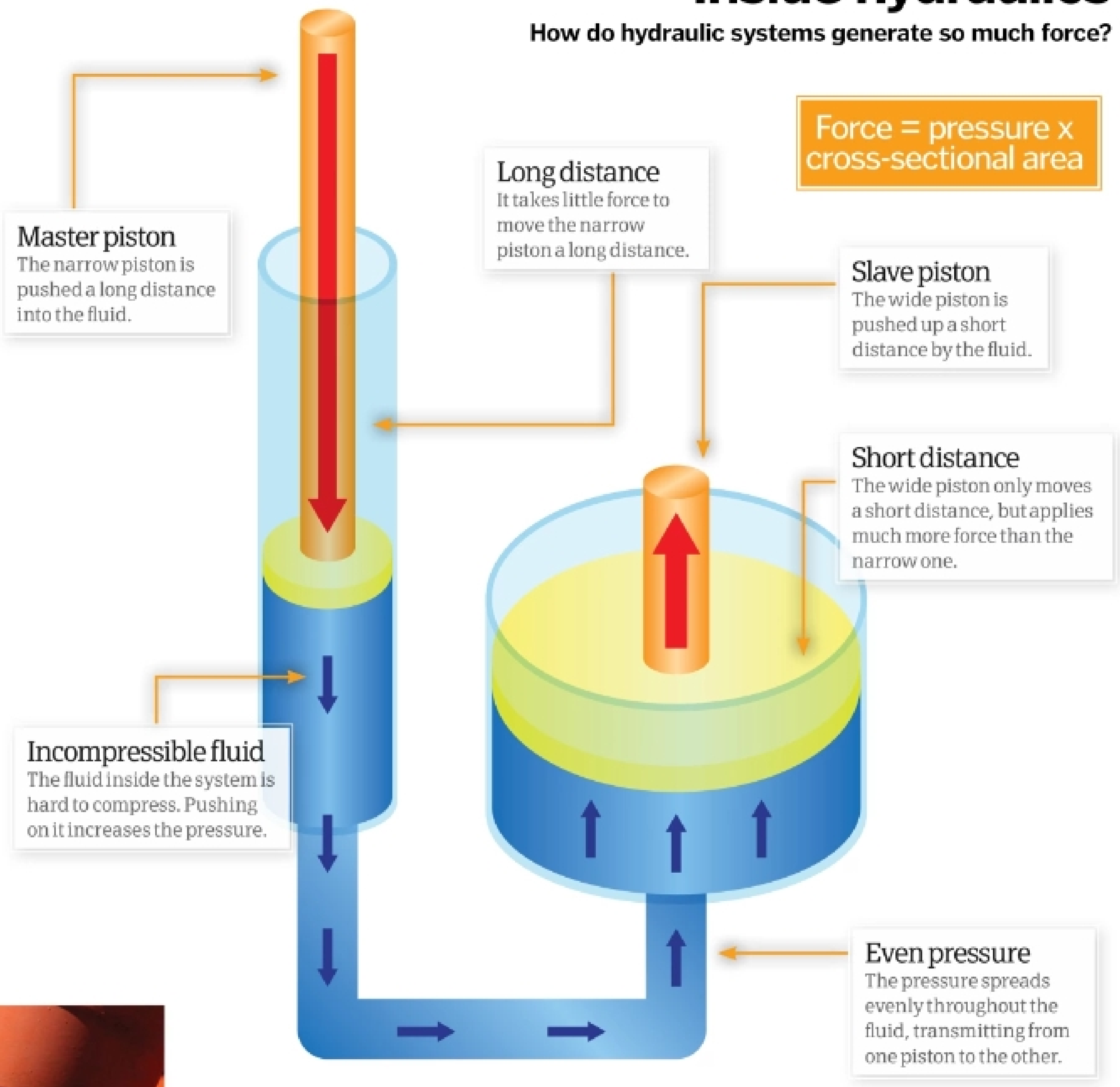
Put a bigger piston at the other end of the container, and the pressure can be used to generate a larger force. You can see why if you rearrange the equation – force is equal to pressure multiplied by cross-sectional area. If the area of the second piston goes up, so does the force that is generated.

Using a small piston to compress a fluid requires little force, but generates a lot of pressure. This pressure can be used to move a larger piston with greater force.

In 1797, Joseph Bramah invented the first hydraulic engine, used to pump beer up from the cellar of a tavern

Inside hydraulics

How do hydraulic systems generate so much force?



Force = pressure x cross-sectional area

Master piston
The narrow piston is pushed a long distance into the fluid.

Long distance
It takes little force to move the narrow piston a long distance.

Slave piston
The wide piston is pushed up a short distance by the fluid.

Short distance
The wide piston only moves a short distance, but applies much more force than the narrow one.

Incompressible fluid
The fluid inside the system is hard to compress. Pushing on it increases the pressure.

Even pressure
The pressure spreads evenly throughout the fluid, transmitting from one piston to the other.

Pascal's principle

Blaise Pascal was a French mathematician in the 17th century, and responsible for our understanding of pressure and hydraulics. He explained that when you push on fluid in a closed container, the pressure is transmitted equally in all directions. A pressure change at one side of the container is transmitted to all other parts of the container, and to the walls. This is known as Pascal's principle.

His work also included understanding atmospheric pressure. So important were his discoveries that the standard unit for pressure was named the Pascal (Pa).

Pascal was a polymath, and also worked on the founding principles of probability with Pierre de Fermat.

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How do nuclear power plants work?

How do we generate electricity by splitting atoms?

Sizewell B is the only nuclear power plant in the UK to use a pressurised water reactor

The power of nuclear fission was first fully realised during World War Two with the invention of the devastating atomic bomb. It was only after the war, when the world had witnessed this incredible release of energy, that attentions were turned to harnessing nuclear reactions as a power source.

Today, nuclear energy is used to power all manner of things from submarines to space probes. Even our own homes are partly nuclear-powered, as roughly 20 per cent of electricity in the UK and the US is provided by nuclear stations.

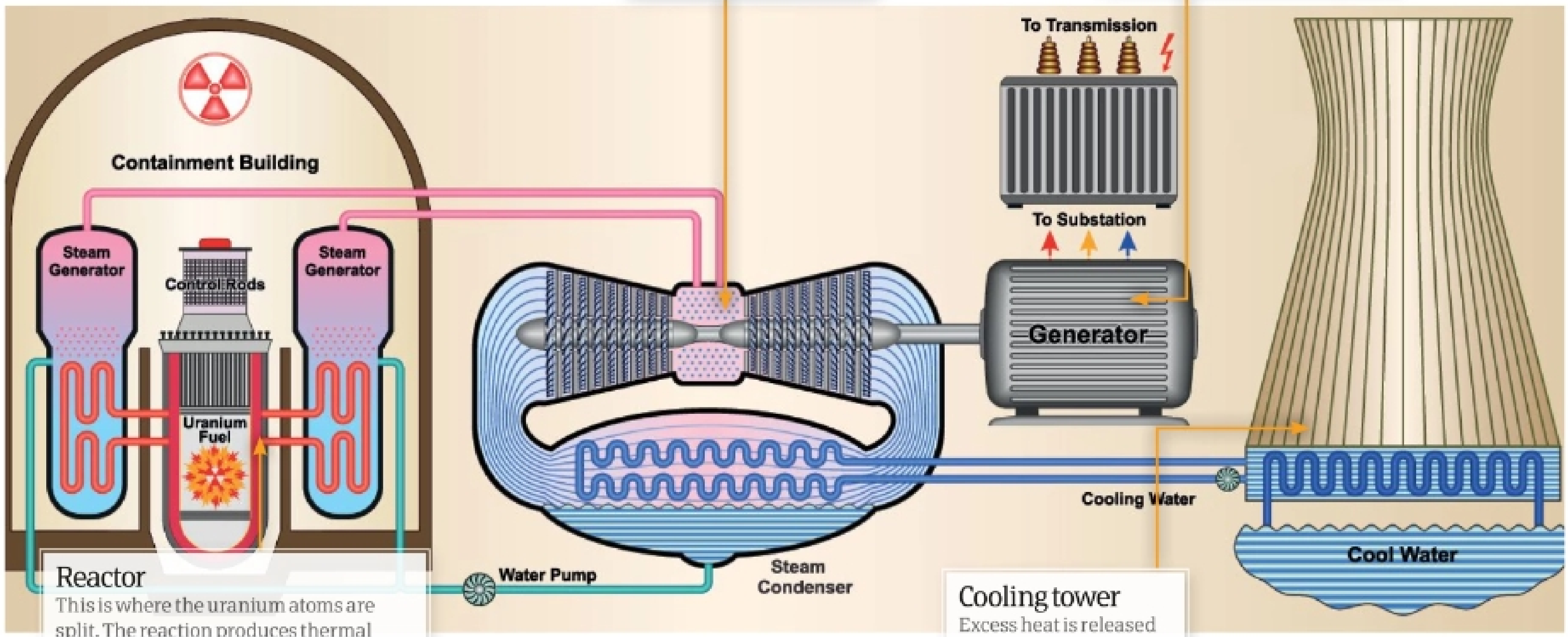
Like most other means of generating electricity, nuclear power plants use heat energy to produce steam that spins turbines. This is a very similar process to burning fossil fuels, currently our main method of producing electricity, but it generates only a fraction of the greenhouse gas emissions.

The fuel used in nuclear power plants is an unstable form of uranium, which releases heat energy when the atom is split in two. In a controlled environment like those found in power plants, this heat can be harvested for efficient energy production. Many people still have concerns about nuclear power due to the radioactive waste that is produced and the potential for devastating accidents – such as the disasters at Chernobyl in 1986 and Fukushima in 2011.

Modern designs of these plants, however, have safety measures in place that ultimately limit exposure of radioactive particles to external materials. New techniques to recycle the radioactive waste are also being developed, which is leading some top scientists to now consider nuclear fission as one of the greenest methods of generating electricity.

How a nuclear power plant works

How do we turn nuclear energy into electricity?



Turbine
The steam produced by the heat of the reaction spins a turbine.

Electricity
Generators transform the kinetic energy of the spinning turbines into electricity.

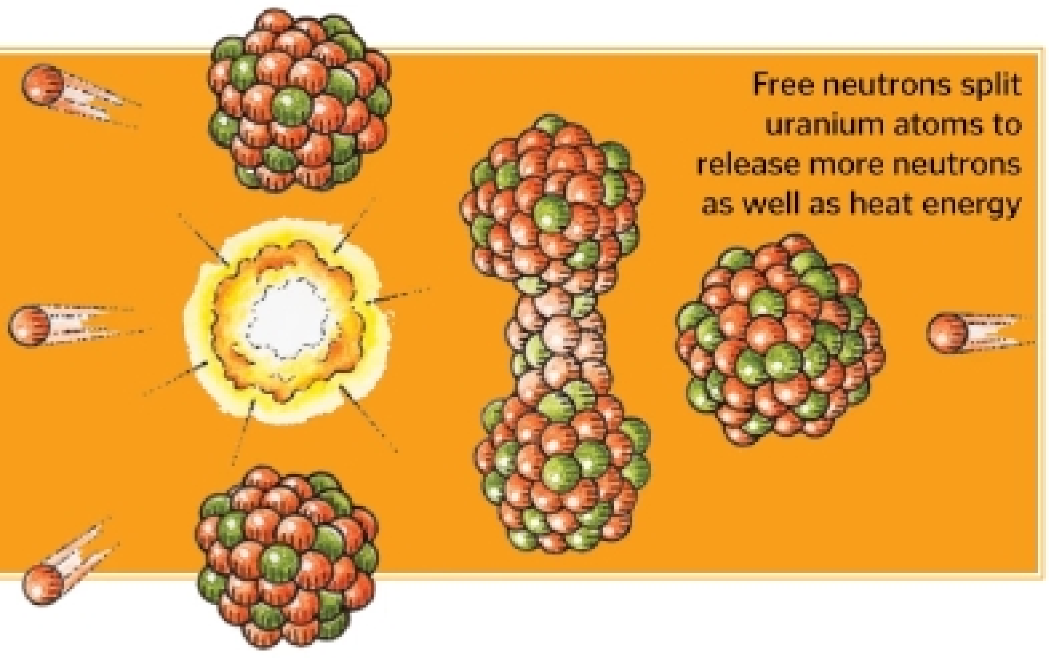
Reactor
This is where the uranium atoms are split. The reaction produces thermal energy that heats a coolant (typically water) in the steam generator.

Cooling tower
Excess heat is released as clean water vapour.

Fission explained

An atom is comprised of a nucleus, formed of neutrons and protons, with electrons orbiting around it. When atoms are split into two or more pieces, we refer to it as fission.

In nuclear fission, the nuclei of uranium atoms are split when they collide with a free neutron. This causes the nucleus to divide and form two separate atoms, releasing energy and more neutrons in the process. These neutrons then collide with other uranium atoms and the result is a chain reaction – neutrons and energy are continuously released until the fuel source is exhausted.


Free neutrons split uranium atoms to release more neutrons as well as heat energy

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Is it true that singing to plants helps them grow?

Not much research has been done on the relationship between music and plant growth, although the theory has been around since the 1850s.

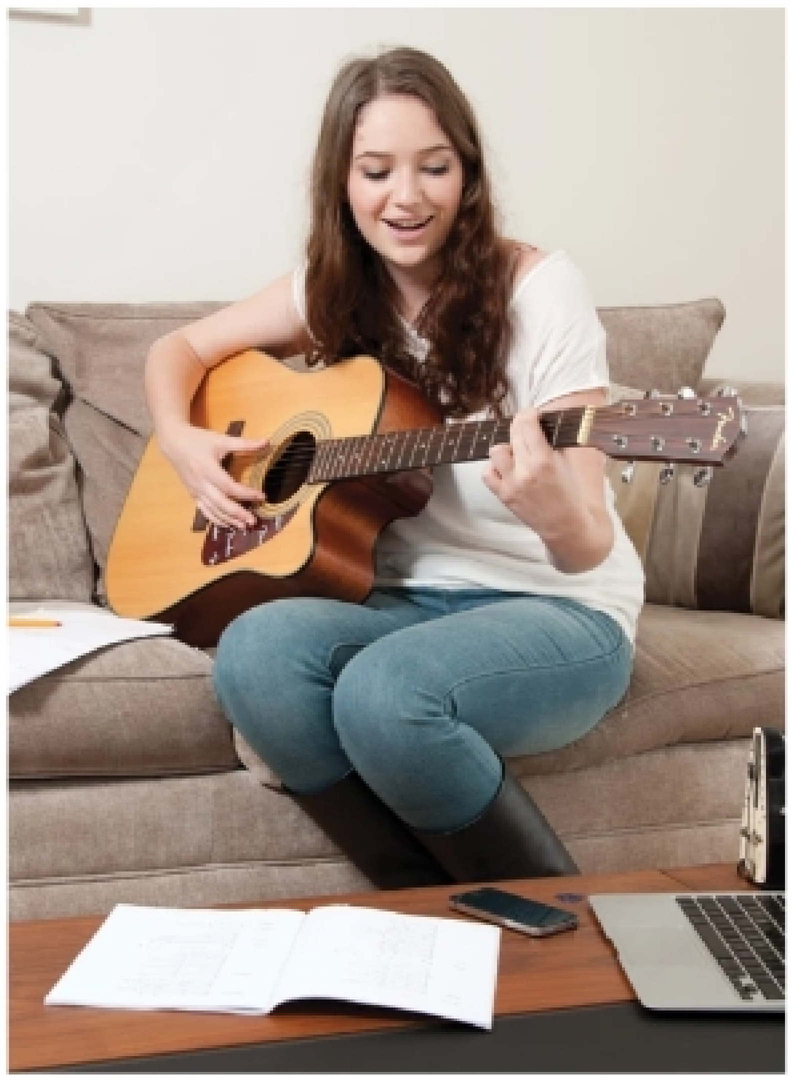
Some researchers believe that sound – if you think of it merely as vibrations – is a form of environmental stimulus that can affect the plant. For instance, perhaps it tends to grow hardier in windy conditions, and the vibrations imitate this. In the most recent experiments, plants that were played music or spoken to did grow better than the control plants left in silence.

However, it's probably more important to provide a plant with light, water and soil than this week's Top 40.

Why are song lyrics so easy to remember?

Our brains seem to be wired to remember song lyrics better than facts, or even what we had for dinner. When you remember the lyrics to a song, you're also remembering the music and the voices, so there are several associations for your brain to access. If you hear the song over and over, repetition also helps you to retain it. It's a form of practice.

The patterns in songs, such as the beat or rhyming lyrics, also help our brains retain them. Finally, if you like the song, your brain will work harder to remember it because of the emotional connection.



What happens in your brain when you feel bored?

The science of boredom hasn't been fully explored, but it is an active area of research. It is linked to attention, and according to researchers at York University in Toronto, Canada, boredom comes down to not being able to engage. When you feel bored, you want something to catch your attention, but it either doesn't or can't. In response, you either start to switch off, or you can begin to get agitated. Boredom is reportedly common in people with chronic attention problems, and in thrill seekers.

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What is white noise?

Just like white light contains all the colours of the spectrum, white noise is made up of all the different frequencies the human ear can hear. It's like listening to all of them at once, at the same level. Because of this, white noise is a very constant sound that can mask others. Some people who can't sleep at night use the static between FM radio stations, which sounds like white noise, to mask sounds that might keep them awake.

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Why does your face turn red when you're angry?

Anger can trigger the fight-or-flight response – an in-built biological reaction that prepares your body to stand up to a threat, or to run away. The body is flooded with two chemical messengers: adrenaline and noradrenaline. They make the heart beat faster, open small airways in the lungs, and increase the rate and depth of breathing. They also trigger the release of sugar into the blood, and increase the delivery of oxygen to your muscles and brain. A common side effect of this is flushing. Adrenaline can cause the blood vessels in the face to get wider, increasing blood flow to the skin.

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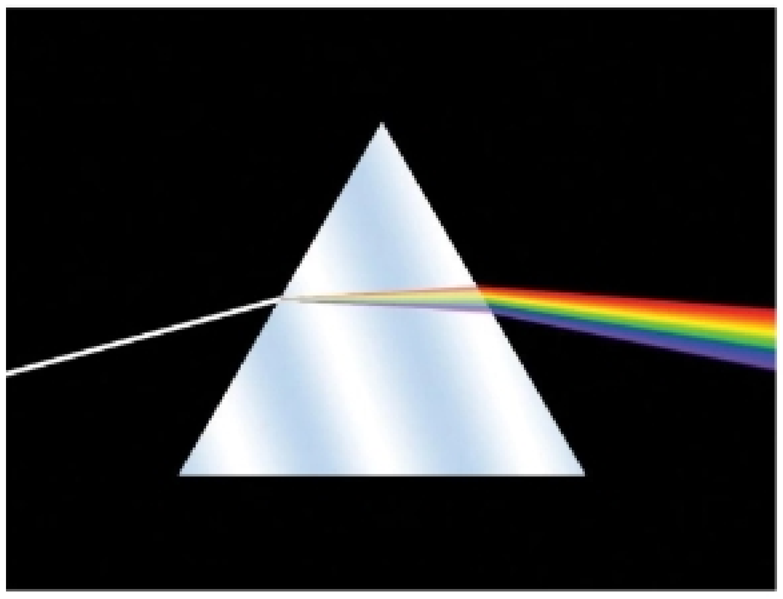
Why do unconscious people feel much heavier?

When a person's muscles are totally relaxed, their weight is distributed unevenly over a wider area. A conscious person will usually tense their muscles when lifted, keeping limbs in or putting their arms around the neck of the person carrying them. This makes the carrier's job easier, as the centre of mass is focused centrally. An unconscious person is limp, allowing their arms and legs to swing around and causing their centre of mass to shift. A fireman's lift allows the carrier to grip the unconscious person better and manage their weight distribution.

What is the wavelength of black and white light?

In terms of the electromagnetic spectrum, black isn't a colour; it's the absence of visible light. The term 'black light' usually refers to a type of lamp that operates in or near the ultraviolet (UV) range. The lamps have a violet filter that block out visible light and let the UV light through. We can't see this type of light, which is why we call it black. White isn't a colour either, instead it's the combination of all of the colours in the visible light spectrum. The wavelengths are between 400 and 700 nanometres, ranging from red to violet.



Is it possible to learn a language while you're asleep?

Maybe! There is evidence to suggest that non-rapid eye movement sleep is an important time for memory consolidation; patterns learnt during the day are reactivated and strengthened at night. In 2014, researchers from Switzerland published results of a study that tested whether playing words during this crucial sleep period could help to trigger these reactivation patterns, assisting with learning. They took 68 healthy volunteers and taught them 120 pairs of words, one in their native language, and the other in a language that they did not know. They were then split into groups, with some of them being played the word pairs again as they slept that night, and others sleeping in silence. When they woke up, the group who had been replayed the words in their sleep were much better at translating them. Unfortunately though, this method only seems to work to consolidate memories. You can't press play on a language tape, fall asleep and wake up fluent – you must do the groundwork while you're awake.

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“There is evidence to suggest that non-rapid eye movement sleep is an important time for memory consolidation”

Who invented Zorbing?

In 1970s France, an architect called Gilles Ebersolt was probably the first to create a giant inflatable plastic ball for people to get inside and roll around, which he named the 'Ballule'. However, Zorbing as we know it today was created in 1994 in New Zealand by Dwane van der Sluis and Andrew Akers. At the time they were trying to develop inflatable shoes for walking on water. When this failed they came up with the idea for a new fun activity using a giant sphere. They called this the Zorb and then spread Zorbing across the world.

Does chicken soup actually help a cold?

Mothers have long prescribed chicken soup for a cold. While eating it can't cure you, there's some science to show that chicken soup is helpful when you're ill. The hot liquid eases congestion and keeps you hydrated, and also contains nutrients with anti-inflammatory properties. In one study, chicken soup kept a type of white blood cell called neutrophils from migrating, which may help reduce cold symptoms. Other nutrients, like Vitamins C, D and E, can also influence immune cells and chemicals.

What makes green tea good for you?

Green tea is sometimes labelled as a 'superfood', but this is nothing more than a marketing term. The claims that this popular beverage can prevent cancer, aid weight loss or slow Alzheimer's disease have not been proven, but green tea does contain vitamins and minerals that are an important part of a healthy diet; it provides B vitamins, manganese, potassium, magnesium and antioxidants called catechins. According to the British Dietetic Association, the evidence that green tea is a miracle food is poor, but it is safe to drink in moderation.

Does drinking alcohol through a straw get you drunk quicker?

The notion that you get drunk faster if you drink through a straw is based on two ideas: first, that you drink faster through a straw than if you were sipping your drink, and second, that by sucking you create a vacuum, which encourages the alcohol to turn to vapour, making it easier to absorb. It is true that inhaling alcohol vapour gets people drunk very quickly. However, the amount of vapour created by drinking with a straw is tiny, and as long as you drink at the same speed, there should be no difference in how quickly you get drunk.

Can humans sense magnetic fields?

There is no conclusive evidence that suggests humans can perceive magnetic fields. However, many animal species do have this ability, which is known as magnetoreception. The mechanism behind this 'sixth sense' remained a mystery until relatively recently, when researchers found that several species,possess proteins called cryptochromes in their eyes. These appear to help them navigate, possibly by 'seeing' magnetic fields as light or dark areas as the proteins align along magnetic field lines.

Humans also have cryptochromes in their retinas. However, numerous studies have attempted to test our perceptions to magnetic fields, and none have proven that we have any ability to do so.

What does chlorine do to our eyes?

Chlorine is used as a disinfectant in pools (between 0.5 and 1.5 milligrams per litre), and in tap water (less than 0.5 milligrams per litre). In tests on healthy volunteers, researchers at Ryogoku Eye Clinic in Japan found that 0.5 milligrams per litre was enough to cause some damage to the cells found in the thin, transparent layer covering the front of the eye. However, getting red, itchy eyes after swimming cannot solely be blamed on chlorine; when the chemical mixes with urine, sweat, oils and cosmetics, it can produce substances that are much more irritating.

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How do antiseptics work?

Antiseptics prevent infection by stopping the growth of bacteria, fungi and other microorganisms. Unlike antibiotics, antivirals and antifungals, these chemicals are only used outside the body, on the skin. Disinfectants are similar, but are used mainly on hard surfaces like counter tops. Most antiseptics work by getting inside microorganisms and disrupting their function, but different chemicals have different effects.

For example, some cause cells to leak or burst open, others interfere with the production of essential molecules, and some prevent microbial cells respiring, grinding their biology to a halt.

Why do balloons hold so much static?

Balloons retain a static electric charge due to the insulating properties of rubber. This material has a high electron affinity relative to hair, so when you rub a balloon against your head, electrons easily come off your hair and build up on the surface of the balloon, and it acquires a negative static charge.

Rubber is an electrical insulator, so electrons cannot move through it easily. The air around the balloons is also an insulator, so the negative charge remains on the balloon's surface.

How do we measure the greenhouse gases being emitted?

Satellites measure greenhouse gases in the atmosphere, while on Earth scientists collect air samples from all over the world. Water vapour and clouds make up the majority of greenhouse gases, with carbon dioxide and other gases comprising about 25 per cent. Current samples are then compared with previous ones, including those from air bubbles that were trapped in ice many thousands of years ago. From this we've determined that the atmosphere contains nearly twice the amount of carbon dioxide (the main greenhouse gas) as there was in 700,000 BCE. With the Industrial Revolution, we began to burn fossil fuels at ever increasing rates, leading to huge jumps in greenhouse gas emissions. In 1750, the atmosphere had a carbon dioxide concentration of about 280 parts per million. By 2000, it was nearly 400 parts per million.

Does music sound any different at high altitudes?

Although atmospheric pressure and density influence the speed of sound, the two effects essentially cancel each other out. At colder temperatures, the molecules in the air carry less kinetic energy, making sound waves travel more slowly. At -1 degrees Celsius for instance, sound travels at 330 metres per second, compared to 344 metres per second at 21 degrees Celsius.

However, the affect this has on the frequency of sound waves – and therefore their pitch – is so small that music would not sound any different.

How high can a helium balloon float?

A balloon is pushed upwards by the difference in pressure between the gas inside and the atmosphere. In theory, it should rise to the point where the atmospheric pressure matches that of the helium – so up to the mesosphere (which starts around 48 kilometres up) but probably not beyond. The problem is that in practice, the same pressure differential that causes balloons to rise also causes them to expand, and then to burst. Using the lightest, stretchiest material they could find, a Japanese team reached a height of 53 kilometres in 2002, hitting the bottom of the mesosphere.

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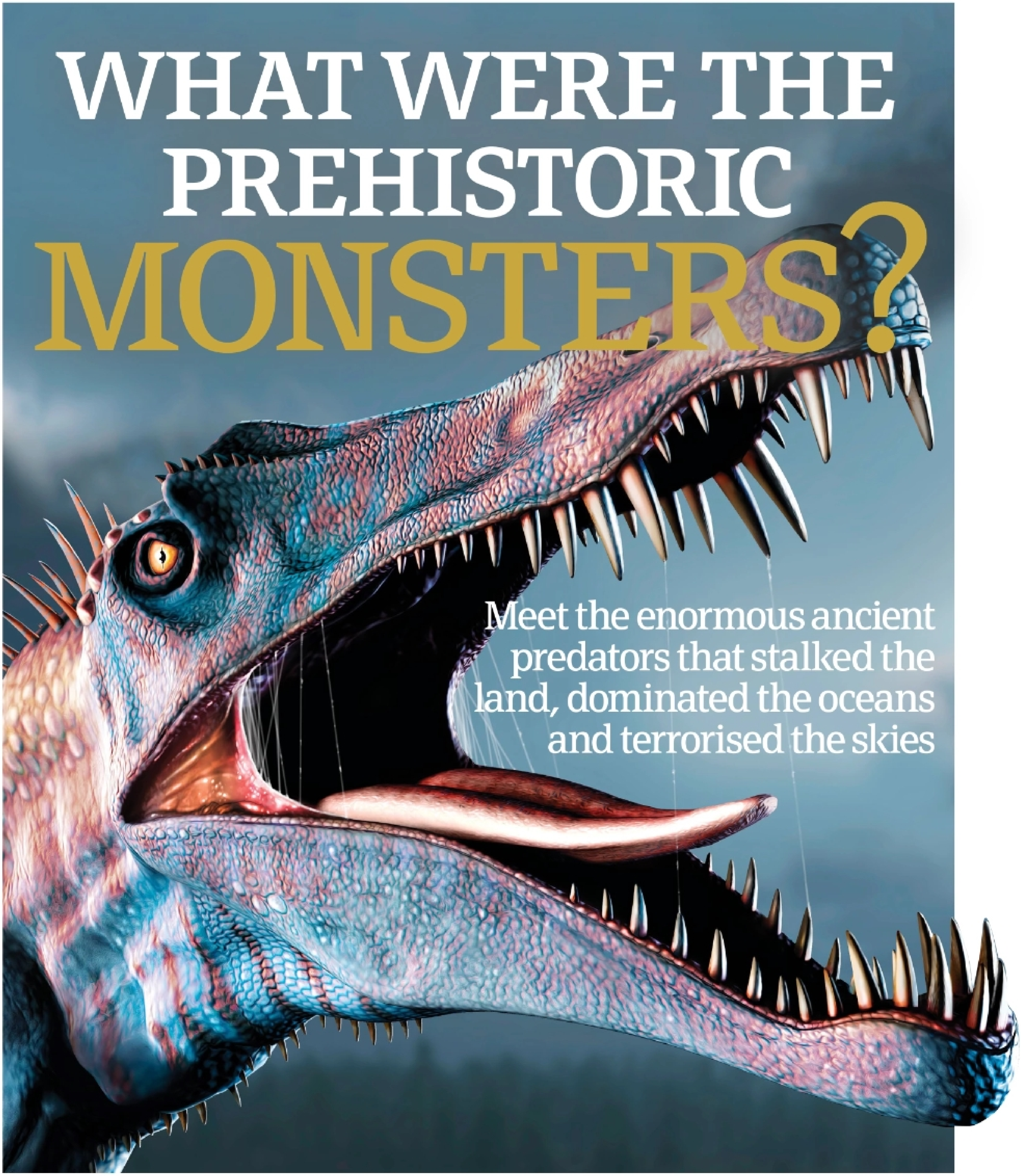
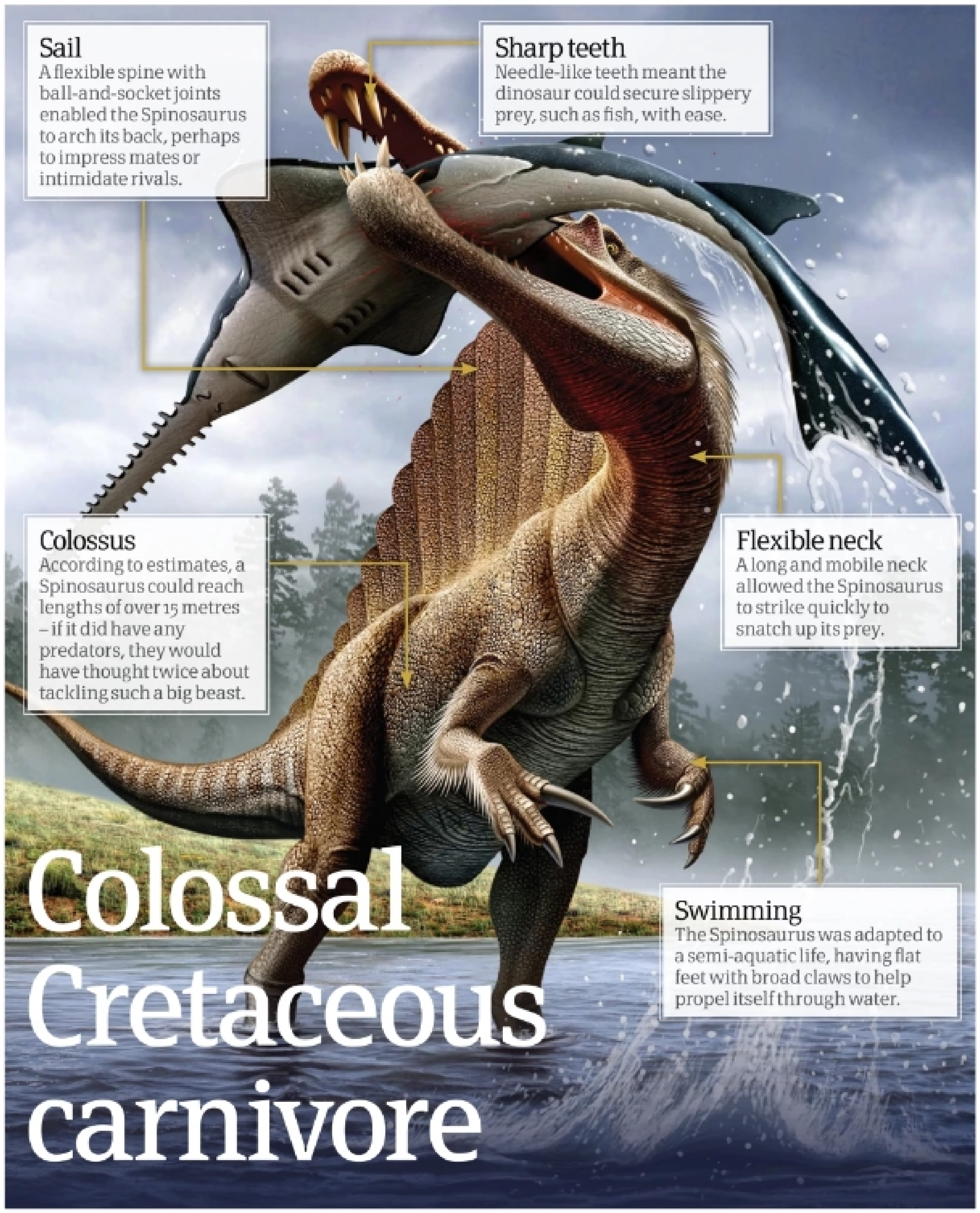
History

104 What were prehistoric monsters?
110 What did it take to become a knight?
111 What jobs were available in the Middle Ages?
112 What was surgery like in the Victorian era?
114 What is the significance of Fabergé eggs?
115 How was the Thames tunnel built?
115 What are the world's tallest statues?
116 What was the biggest sloth?
117 How were typewriters built?
118 How do fossils form?
120 Bitesize Q&A

WHAT WERE THE PREHISTORIC MONSTERS?



Meet the enormous ancient predators that stalked the land, dominated the oceans and terrorised the skies



Sail
A flexible spine with ball-and-socket joints enabled the Spinosaurus to arch its back, perhaps to impress mates or intimidate rivals.

Sharp teeth
Needle-like teeth meant the dinosaur could secure slippery prey, such as fish, with ease.

Colossus
According to estimates, a Spinosaurus could reach lengths of over 15 metres – if it did have any predators, they would have thought twice about tackling such a big beast.

Flexible neck
A long and mobile neck allowed the Spinosaurus to strike quickly to snatch up its prey.

Swimming
The Spinosaurus was adapted to a semi-aquatic life, having flat feet with broad claws to help propel itself through water.

Colossal Cretaceous carnivore

SPINOSAURUS ▶ 112-97 MYA

Move over T rex: the spine lizard was the true king

Nearly three storeys high and longer than a bus, the Spinosaurus was the largest carnivorous dinosaur to walk the Earth. The 'spine lizard' roamed the coastal plains and swamps of North Africa in the mid-Cretaceous period.

Unlike the Tyrannosaurus rex, Spinosaurus' teeth were not serrated, so they were not used for tearing through flesh; its conical teeth, powerful jaws and long snout were better suited to snapping up large fish. It's thought that Spinosaurus was the first dinosaur to swim, and that it spent a lot of time in the water where it could snatch aquatic creatures with its razor-sharp claws. There is evidence to suggest Spinosaurus' snout openings and skull cavities were part of a pressure-detection system, so it could sense the movements of fish even in murky waters.

The giant carnivore's defining feature was the 1.5-metre-high 'sail' on its back, formed by tall vertebral spines. This may have been a display to attract mates or intimidate rivals, help regulate temperature, or possibly support a camel-like hump of stored fat that Spinosaurus could build up when food was plentiful.

Mega monitor lizard

VARANUS PRISCUS ▶ 1.8 MYA-40,000 YA

Also known as Megalania, these giant goannas of eastern Australia were the largest land lizards of all time. They could grow to lengths of over five metres and weigh as much as 600 kilograms. Megalania had razor-sharp teeth and claws, perfect for tearing into its prey. These large lizards compensated for their lack of speed by lying in wait to ambush victims, and sought out carrion using their excellent sense of smell.

Super-sized serpent

TITANOBOA ▶ 60-58 MYA

Reaching lengths of up to 15 metres, Titanoboa was one of the largest land animals on Earth following the extinction of the dinosaurs. These colossal serpents lived in the jungles of South America, devouring turtles and crocodiles in single mouthfuls. Titanoboa could hunt on land and in water, slithering or swimming up to its prey undetected, then suddenly leaping up to clamp its powerful jaws over the victim's windpipe.

Terror birds

PHORUSRHACIDAE ▶ 62-2 MYA

These terrifying predators of prehistoric South America were members of the Phorusrhacidae family, known as 'terror birds', and some could reach heights of three metres. Their main weapon was a sharp, hooked beak that could strike victims from above like a pickaxe. The birds' legs were also incredibly strong, and they may have used their feet to kill by repeatedly kicking, or thrown their prey violently to tenderise the meat.

© Alamy; SPL

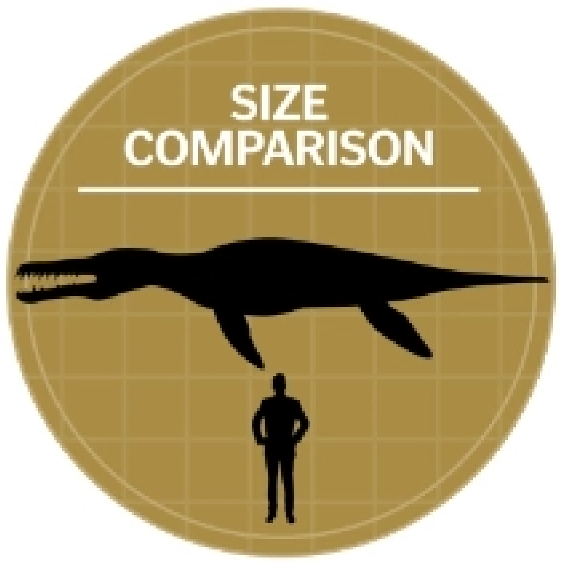
Mighty ocean predator

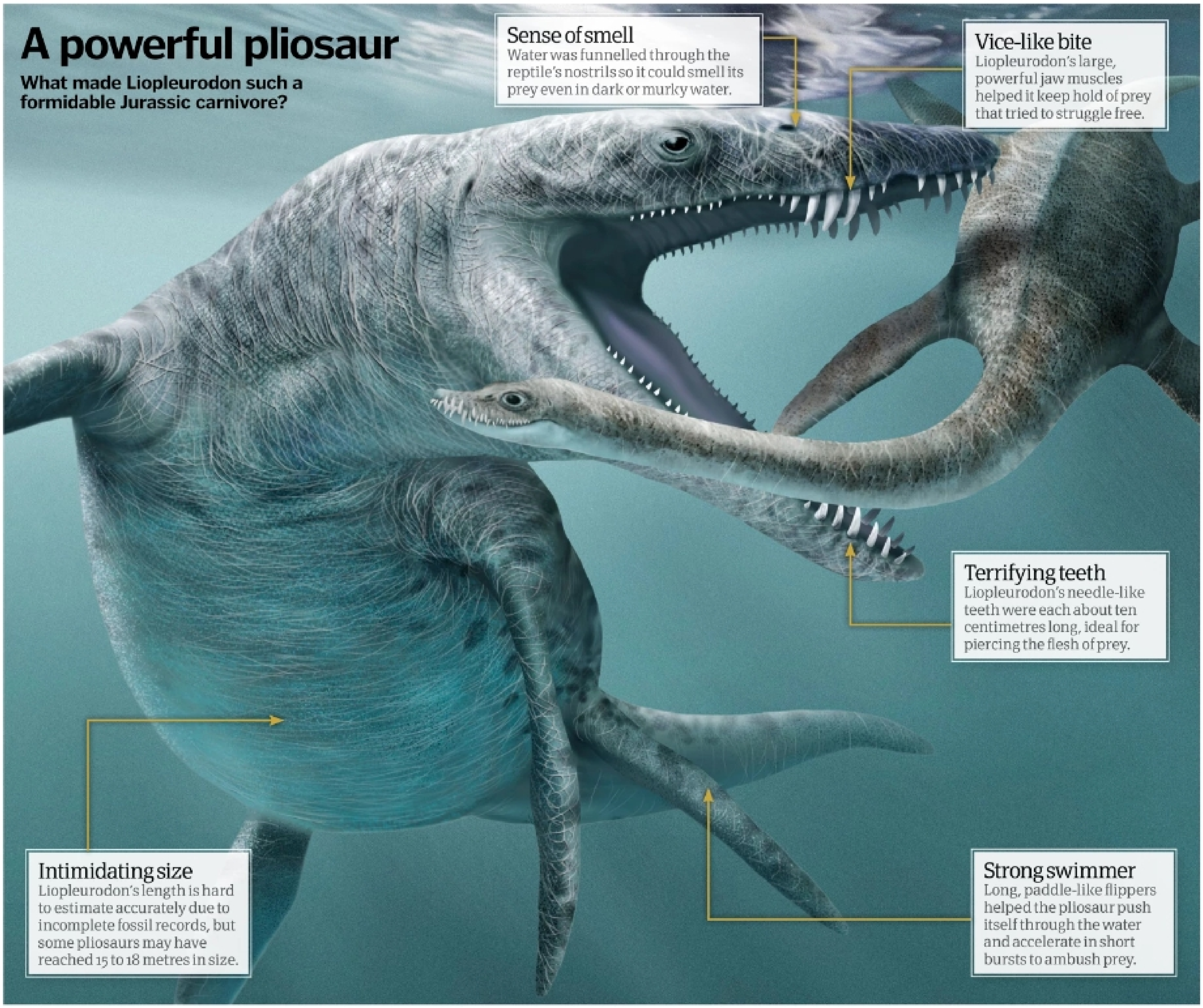
Lurking in the depths of prehistoric seas were a whole host of deadly aquatic giants

LIOPLEURODON ▶ 160-155 MYA

Liopleurodon was among the most powerful predators ever known on Earth, with a bite possibly even stronger than that of the mighty T rex. It belonged to a group of marine reptiles called pliosaurs, which were large with short necks. Liopleurodon's diet primarily consisted of fish and squid, but it would occasionally seek out much larger prey. Huge bite marks that were found in plesiosaur fossils suggest that they were victims of the Liopleurodon's massive jaws, which were packed with sharp teeth. Scientists even estimate that these colossal carnivores would have been strong enough to bite a car in half, if they had existed at the same time!

Liopleurodon may have also had a pale underside to help keep it camouflaged from prey below, allowing it to make ambush attacks despite its enormous size.





A powerful pliosaur

What made Liopleurodon such a formidable Jurassic carnivore?

Sense of smell
Water was funnelled through the reptile's nostrils so it could smell its prey even in dark or murky water.

Vice-like bite
Liopleurodon's large, powerful jaw muscles helped it keep hold of prey that tried to struggle free.

Terrifying teeth
Liopleurodon's needle-like teeth were each about ten centimetres long, ideal for piercing the flesh of prey.

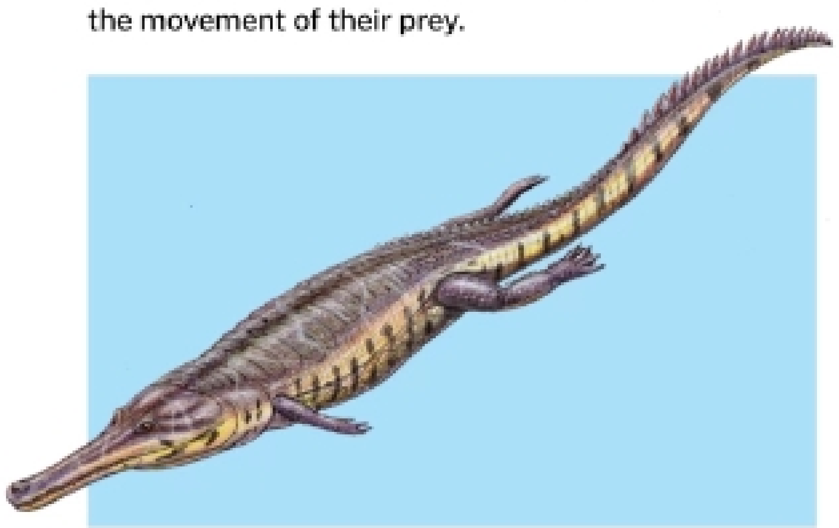
Intimidating size
Liopleurodon's length is hard to estimate accurately due to incomplete fossil records, but some pliosaurs may have reached 15 to 18 metres in size.

Strong swimmer
Long, paddle-like flippers helped the pliosaur push itself through the water and accelerate in short bursts to ambush prey.

Giant sea scorpion

PENTECOPTERUS ▶ 467 MYA

Over 200 million years before the first dinosaurs emerged, this nightmarish Pentecopterus was an important Palaeozoic predator. These arthropods grew to lengths of around 1.8 metres, and used their large limbs to grab prey. Young lived on the seabed while adults mainly resided in shallow waters to avoid larger predators. These super-sized scorpions also had hairs that helped them to sense the movement of their prey.



King-sized croc

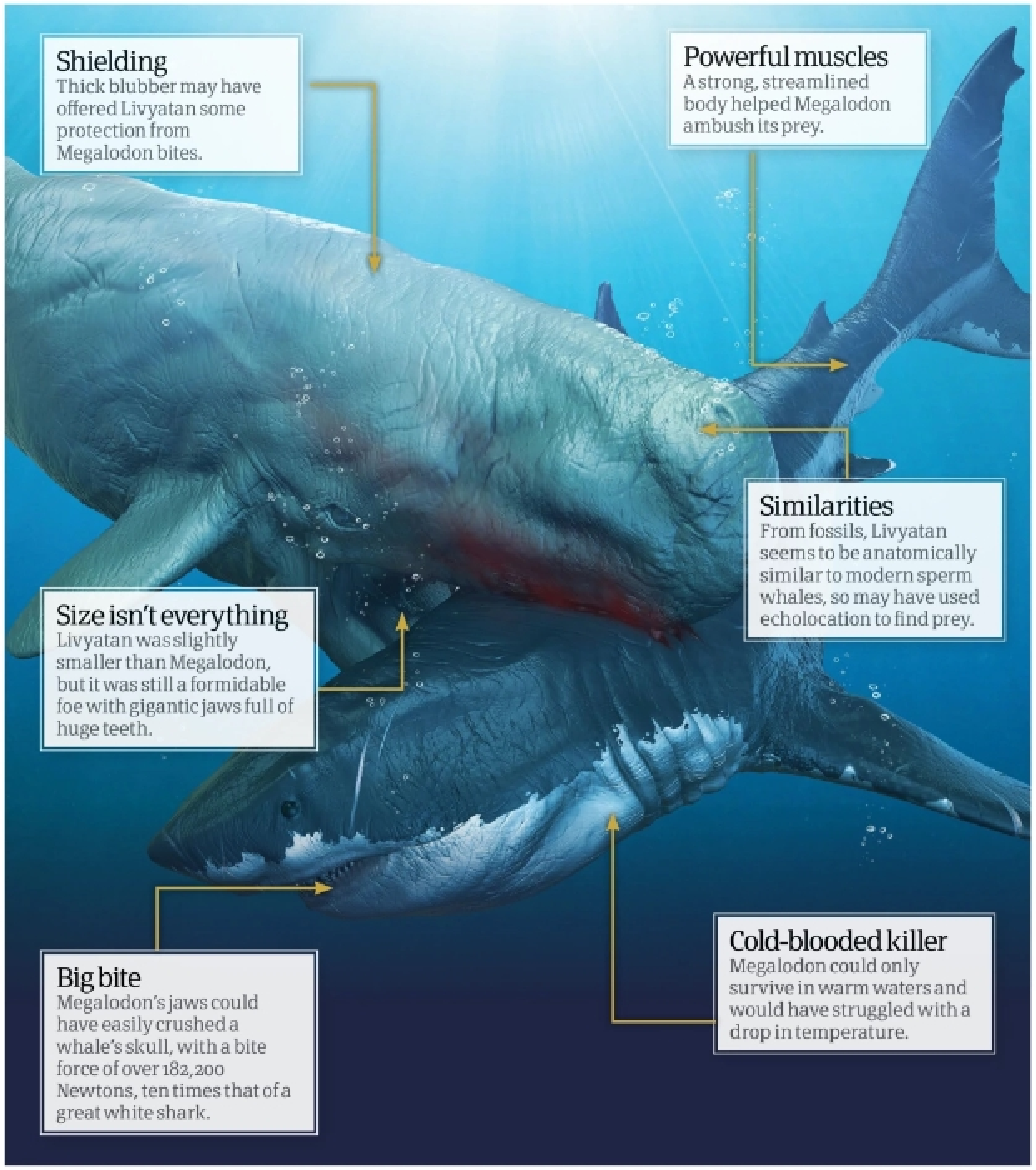
MACHIMOSAURUS ▶ 130 MYA

Lurking in Cretaceous seas, Machimosaurus was a colossal crocodile at nearly ten metres long, almost twice the size of its biggest modern relatives. Its teeth were best suited for crushing shells and crunching bones rather than slicing through flesh. Machimosaurus' main tactic was to hide in shallow water and, without warning, clamp its mouth shut on a turtle or fish. Once its prey was caught in the jaws, there would be no escape.

Apex ocean reptile

MOSASAURUS ▶ 80-66 MYA

The massive Mosasaurus was a giant aquatic lizard and dominant predator in Cretaceous-era oceans. Some grew to 15 metres or more, and had long, powerful tails to propel themselves through water. They preyed on reptiles, fish, sharks and shellfish, snapping their tough shells with its powerful jaws. As an air-breather, Mosasaurus was unable to dive for prolonged periods, so it was limited to hunting near the ocean surface.



Shielding
Thick blubber may have offered Livyatan some protection from Megalodon bites.

Powerful muscles
A strong, streamlined body helped Megalodon ambush its prey.

Similarities
From fossils, Livyatan seems to be anatomically similar to modern sperm whales, so may have used echolocation to find prey.

Size isn't everything
Livyatan was slightly smaller than Megalodon, but it was still a formidable foe with gigantic jaws full of huge teeth.

Big bite
Megalodon's jaws could have easily crushed a whale's skull, with a bite force of over 182,200 Newtons, ten times that of a great white shark.

Cold-blooded killer
Megalodon could only survive in warm waters and would have struggled with a drop in temperature.

Megalodon vs livyatan

Who would emerge victorious between the two prehistoric goliaths?

LIVYATAN ▶ 13-12 MYA

A killer sperm whale with one of history's biggest bites

Hebrew for 'leviathan', Livyatan was roughly the same size as a modern sperm whale, but it was a much more formidable hunter. The 50-ton beasts probably competed with Megalodon for food, preying on smaller whales, cetaceans like dolphins, and large fish. Livyatan teeth are possibly the largest of any animal at over 30 centimetres long, and its bite force could rival that of the Megalodon.

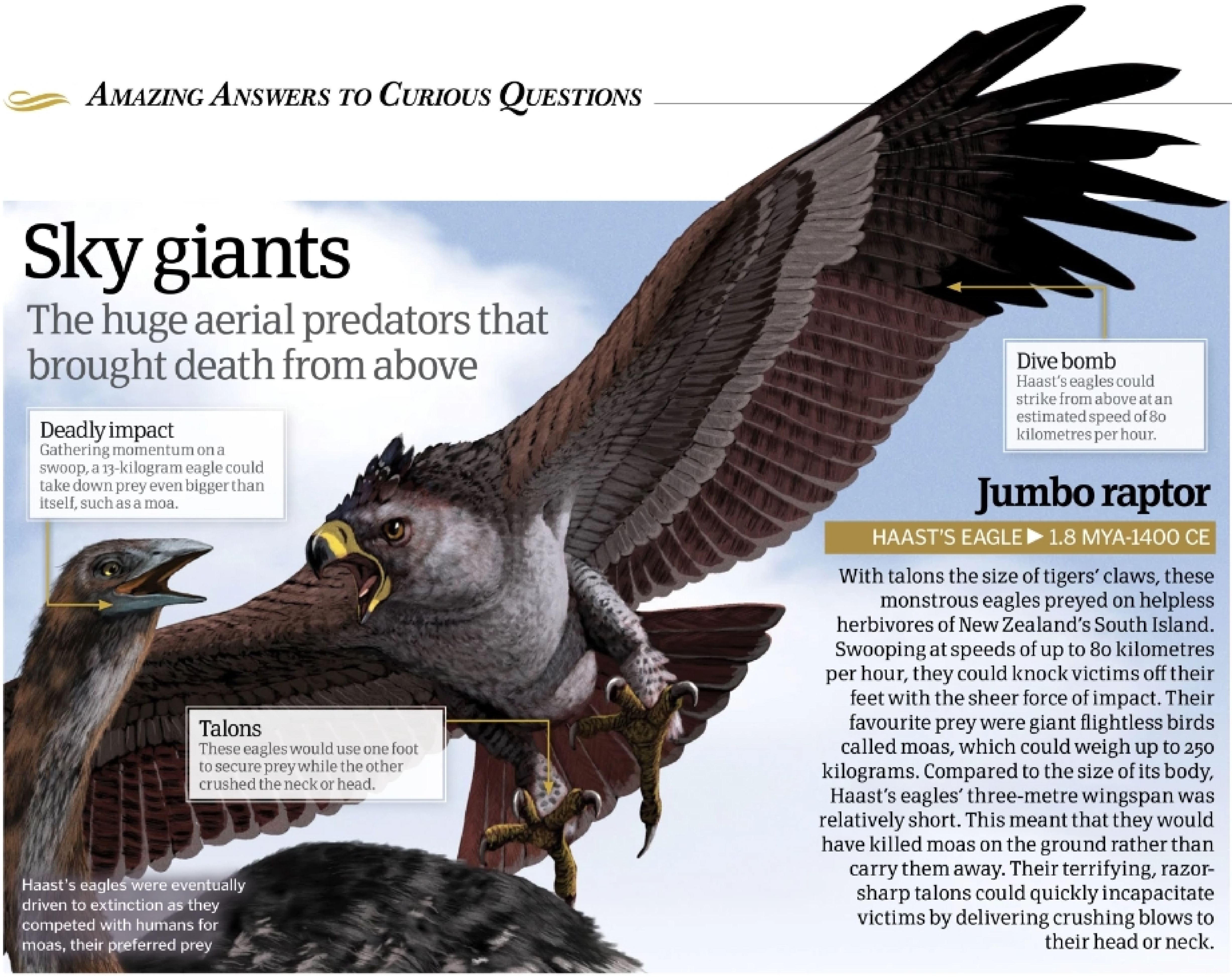
MEGALODON ▶ 28-1.6 MYA

Meet the colossal sharks that dwarfed great whites

These gigantic 75-ton sharks were so big that they could hunt whales with ease. Up to 20 metres long and equipped with a mouth full of teeth as large as a human hand, these mega-sharks made short work of dolphins, whales, seals, squid and other sharks. When faced with a turtle shell, they snapped it in two. It is estimated that Megalodon had one of the strongest bite forces of any animal that's ever lived, capable of crushing a small car.

Sky giants

The huge aerial predators that brought death from above



Deadly impact
Gathering momentum on a swoop, a 13-kilogram eagle could take down prey even bigger than itself, such as a moa.

Talons
These eagles would use one foot to secure prey while the other crushed the neck or head.

Dive bomb
Haast's eagles could strike from above at an estimated speed of 80 kilometres per hour.

Jumbo raptor

HAAST'S EAGLE ▶ 1.8 MYA-1400 CE

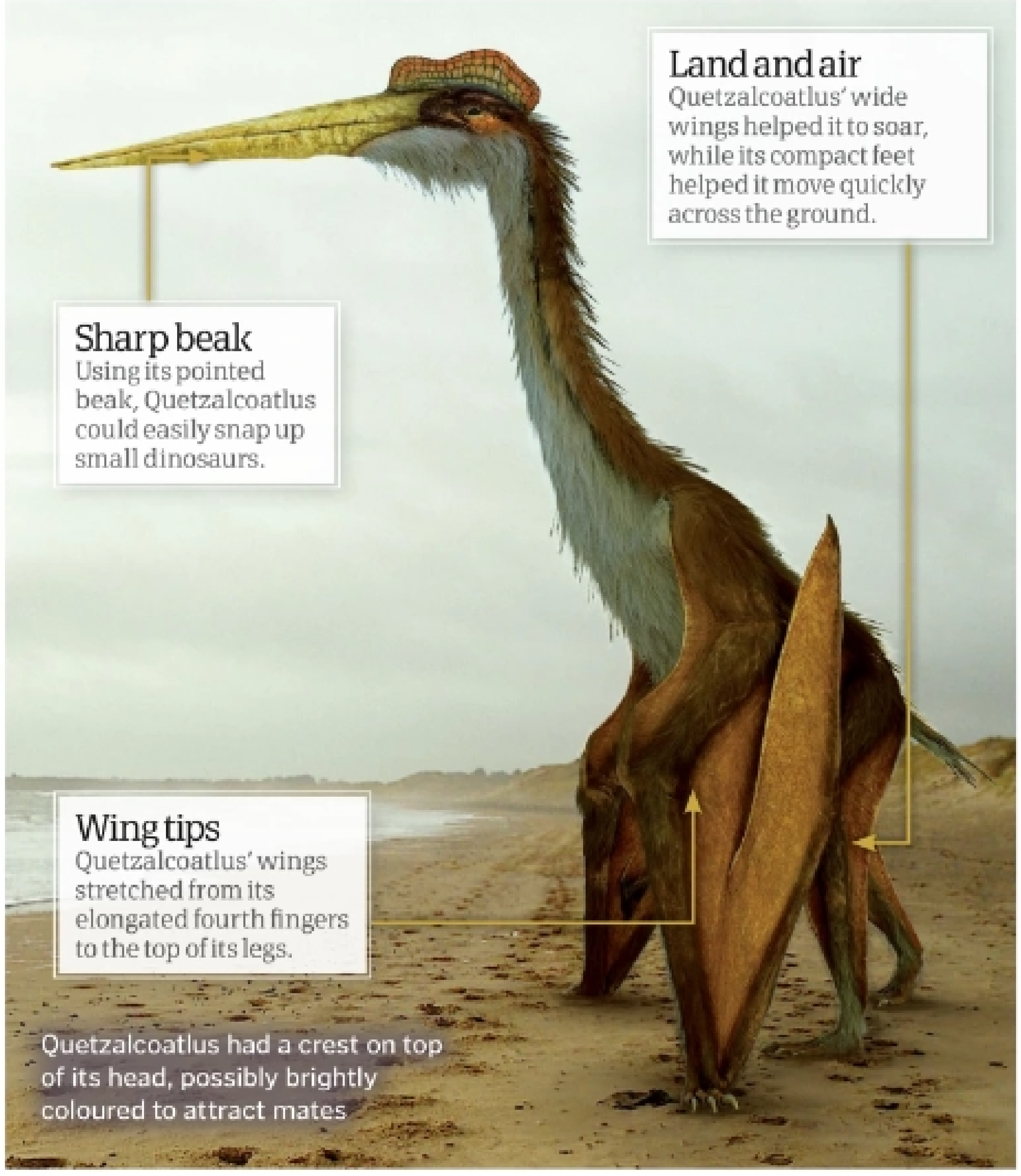
With talons the size of tigers' claws, these monstrous eagles preyed on helpless herbivores of New Zealand's South Island. Swooping at speeds of up to 80 kilometres per hour, they could knock victims off their feet with the sheer force of impact. Their favourite prey were giant flightless birds called moas, which could weigh up to 250 kilograms. Compared to the size of its body, Haast's eagles' three-metre wingspan was relatively short. This meant that they would have killed moas on the ground rather than carry them away. Their terrifying, razor-sharp talons could quickly incapacitate victims by delivering crushing blows to their head or neck.

Haast's eagles were eventually driven to extinction as they competed with humans for moas, their preferred prey

Plane-sized pterosaur

QUETZALCOATLUS NORTHROPI ▶ 70-65 MYA

Quetzalcoatlus was the largest-known species of pterosaur, the group of flying reptiles that lived alongside dinosaurs. With a wingspan of ten metres or more, it was roughly the size of a small jet plane. Its toothless beak suggests that it hunted small prey that didn't require chewing, such as baby dinosaurs, and possibly also scavenged for carrion. Quetzalcoatlus is also thought to have roamed on land, because it had small, cushioned feet that were suited to moving over firm terrain. If this is true, it may have hunted like a modern-day stork, snatching small prey up in its beak.



Land and air
Quetzalcoatlus' wide wings helped it to soar, while its compact feet helped it move quickly across the ground.

Sharp beak
Using its pointed beak, Quetzalcoatlus could easily snap up small dinosaurs.

Wing tips
Quetzalcoatlus' wings stretched from its elongated fourth fingers to the top of its legs.

Quetzalcoatlus had a crest on top of its head, possibly brightly coloured to attract mates

Biggest bird

ARGENTAVIS ▶ 6 MYA

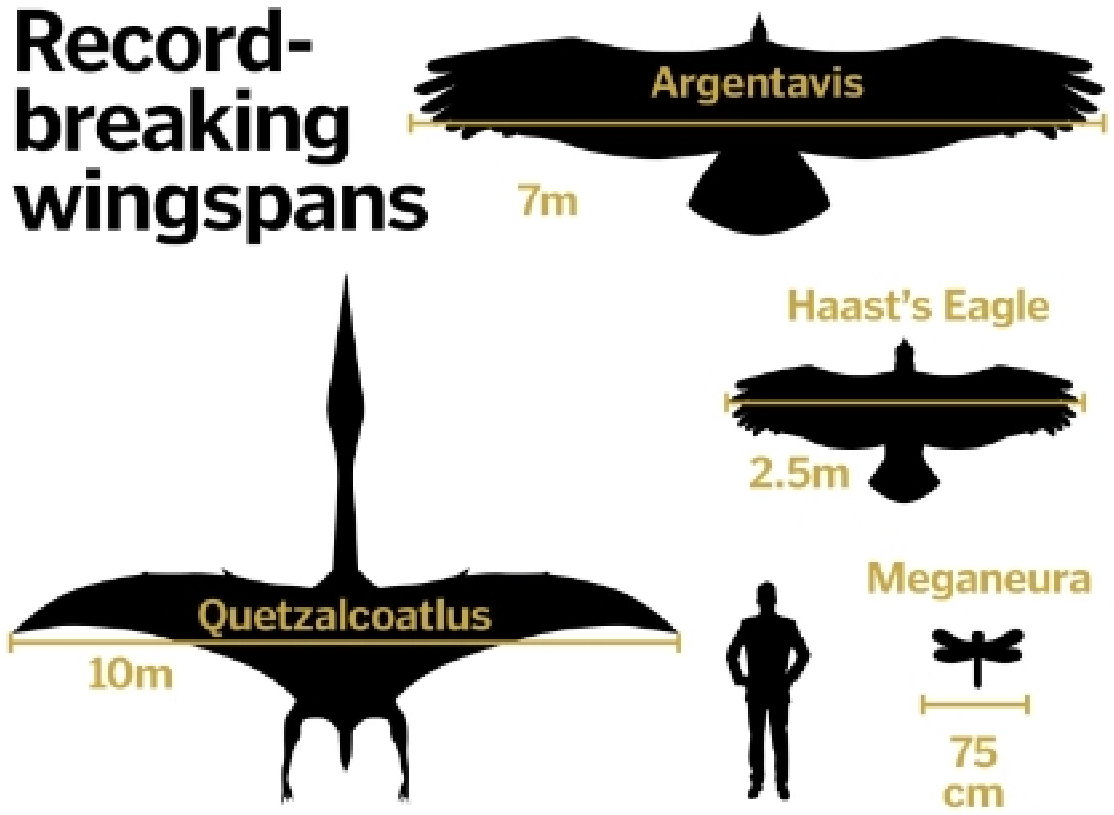
Dwarfing even the Haast's eagle, Argentavis is one of the largest birds to have ever lived. Its seven-metre wingspan meant it was suited to gliding rather than flapping, and it used air currents to stay aloft. Argentavis' massive size made it impossible to perform a running take-off, so it relied on height to get airborne, taking advantage of slopes and headwinds like a hang-glider pilot. The so-called 'monster bird' could use its sharp talons and hooked beak to attack its prey, soaring over vast areas of land in search of victims. Argentavis may have also scavenged, its intimidating size driving other hunters away from a kill, in order to help itself to the carcass.

Gliding bird
Argentavis' long wings enabled it to glide on wind currents and updrafts.

Achieving flight
To get airborne the bird would run down slopes and leap into the air.

Scavenger
Argentavis' imposing size meant it could scare away other predators from their own kills.

Record-breaking wingspans



Gigantic fly

MEGANEURA ▶ 300 MYA

One of the biggest insects to ever exist, the Meganeura was a member of the griffinflies, which are closely related to dragonflies. This prehistoric insect benefited from a higher percentage of oxygen in the atmosphere in the period in which it lived. This allowed it to grow to and maintain its huge size. It used its large eyes to spot prey such as small amphibians and other insects, which it grabbed with its legs while in midair.

Why were prehistoric animals so big?

It had previously been accepted that prehistoric animal size was a result of Cope's Rule. Named after American palaeontologist Edward Drinker Cope, the theory suggested that dinosaur gigantism was down to the notion that animals naturally evolve to be bigger. When mass extinctions occur, new smaller animals replace the larger extinct ones, and the process begins anew. As it has 'only' been 66 million years since the Cretaceous mass extinction, and 12,000 years since the last ice age, animals on Earth are now smaller because they haven't yet had enough time to evolve to reach such large sizes once again.

Another theory suggested that environmental factors, such as higher oxygen levels and warmer temperatures, could have played a significant role in gigantism. Cold-blooded reptiles benefited from the toasty climate as it allowed for efficient digestion, circulation and respiration, as well as an abundance of vegetation to consume. More recent research and fossil discoveries have cast doubt on both these theories, though. Some creatures seemed to evolve to be smaller rather than larger over time, and many different-sized animals existed at the time. One explanation for why dinosaurs in particular were typically large is because they where physiologically similar to birds. Their bones had air pockets in them, making even large species relatively light, so they wouldn't collapse under the weight of their own bodies.

Not all of the biggest beasts were prehistoric, though. In fact, the heaviest animal ever to exist on planet Earth is still alive today: the blue whale. Marine animals can grow to epic proportions because the buoyancy from water helps to balance the force due to gravity. This supports their considerable masses, and allows for far larger body sizes than on land.

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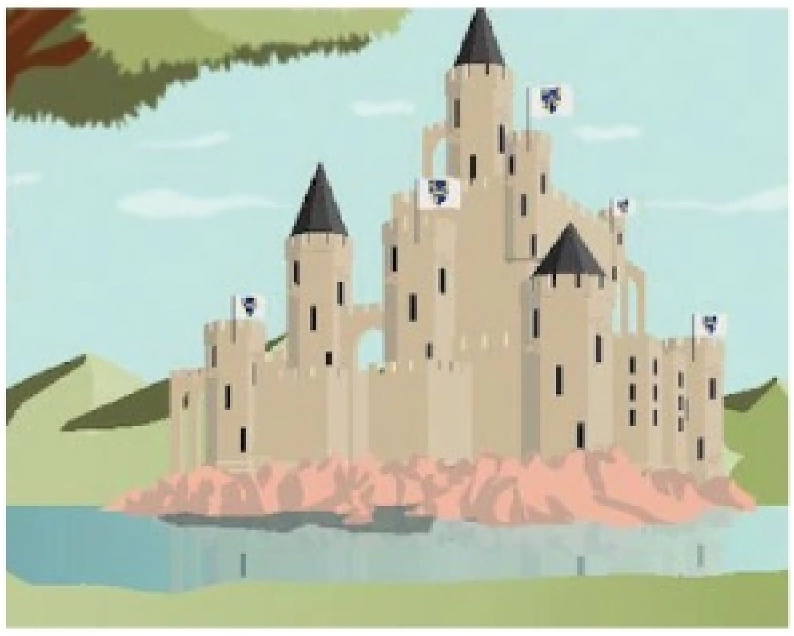
What did it take to become a knight?

The intensive training required to achieve knighthood in the Middle Ages

Knights were mounted armoured warriors of the Medieval era. Their place in society was below lords and above peasants and they would earn a living by protecting the realm from attack. In return, the nobility would grant land to the knights but the wealthy barons would only hire those who were skilled in combat. A boy's education could take over ten years as they progressed from page to squire to mounted warrior. The apprenticeship may have begun on a wooden horse in a manor house, but it many cases it finished on a stallion in the heat of battle.

The road to knighthood

From page to knight, training was an arduous yet rewarding journey



1 Starting out

Although it was technically possible for any boy to become a knight, those born into nobility had a distinct advantage. Training was expensive, and they would also need to be kitted out with weapons and a horse. Because of this, in most cases only the very rich could afford to become knights.

2 A young page

The journey to knighthood began as a page. At the age of seven, a boy was sent away to a noble household to serve a knight. Here, he would be taught chivalry – the qualities expected from a knight, including courage and honour – and other physical skills such as archery and swordsmanship.

3 Horsemanship

One of the most important skills a trainee knight needed to master was riding a horse. Pages practised on wooden horses until they became squires at the age of 14. As well as riding, the squires would also help take care of the horses and clean the knight's armour.

4 First taste of battle

There's no better training than experiencing battle first-hand. A military force in the Middle Ages needed every man it could muster and knights that graced the battlefield often had squires. All the techniques and skills learnt in training led to this.

5 The making of a knight

Further battles would provide more opportunities for squires to strengthen their fighting skills. Now a relative veteran, they could gain experience in different situations such as mounted attacks, siege warfare and close-quarters combat.

6 Arise, Sir Knight!

If a squire had proven himself to be skilled and brave on the battlefield, he would be given his knighthood at the age of 21. During the 'dubbing' ceremony, he would kneel before another knight, a king or a lord, and be tapped on the shoulder with a sword.

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What jobs were there in the Middle Ages?

From catching rats in sewers to juggling for the king, discover the strange careers that were available

In the Medieval era, you could be a professional rat catcher

The job opportunities open to you in medieval times largely depended on your social class. Those with status were typically nobles, members of the clergy or employed by the royal court, while the peasants, or those without status, worked as craftsmen or labourers. In between were the merchants, who became wealthy by trading the products made by skilled workers all over the world.

All roles were important, as they ensured everyone had the goods and services they needed to go about their lives, but the lower-class workers were often exploited. As a result, the guild system was established. Guilds were organisations that promoted the economic welfare of their members, much like today's trade unions. Most professions had a guild, from merchants and weavers to blacksmiths and candlemakers. Members would set prices and standards for their trade; thusly, anyone seeking employment could pay to join and be trained in the represented craft.

Herbalist

Using practical herbal remedies derived from plants and other natural sources, these so-called 'wise women' could treat a wide range of medical conditions. Providing a lifeline for those who could not afford the services of a trained physician, their knowledge of folk medicine was then passed down through the generations.

Squire

Promoted from the position of page boy at 14, a squire was the servant to a knight, and often accompanied him into battle. In return, he would be taught the code of chivalry, the rules of heraldry, bravery, horsemanship, swordsmanship, and other athletic skills, before being promoted to knighthood at the age of 21.

Court jester

Employed by the royal court to entertain the king, a jester would juggle, tell jokes, perform tricks, and generally clown around to improve his master's mood. In return, he was paid well and given a place to live, and enjoyed certain privileges, including being able to make fun of nobles and get away it.

Blacksmith

Every village had its own blacksmith, who would make everything from weapons and tools to door knobs and jewellery. Using charcoal as fuel, they would heat iron until it became malleable, then hammer it into various shapes on a heavy block known as an anvil.

Rat catcher

Rats were a big problem in medieval Europe, spreading diseases and eating crops. Accompanied by a small dog or cat to sniff out the vermin, and various traps and poisons to capture or kill them, rat catchers would walk the streets and sewers, risking contracting the plague to earn a living.

Herald

With so many knights scattered across Europe, each with their own coat of arms, it was the job of a herald to keep track of them all. This also helped them in their other main duty: conducting and announcing the participants of jousting tournaments.

Scribe

As there were no printing presses in medieval times, scribes would copy out text in order to create additional copies of books. This role was often afforded to monks, because they had been taught to read and write, and was hard work, illustrated by the complaints they would often write in the manuscript margins.

Barber

Offering much more than a haircut, medieval barbers would often perform medical procedures too. Known as barber surgeons, they would extract teeth, amputate limbs and carry out bloodletting, the practice of draining the blood to 'cure' illnesses. With no anaesthetic or training, and only basic tools, it was often very messy.

Spinster

In order for wool to be woven, it first had to be turned into yarn. Typically this role was held by women, but male 'spinners' did also exist. They would first twist the fibres between their thumb and forefinger, then attach them to a drop-spindle, the weight of which would stretch the fibres into yarn as they spun.

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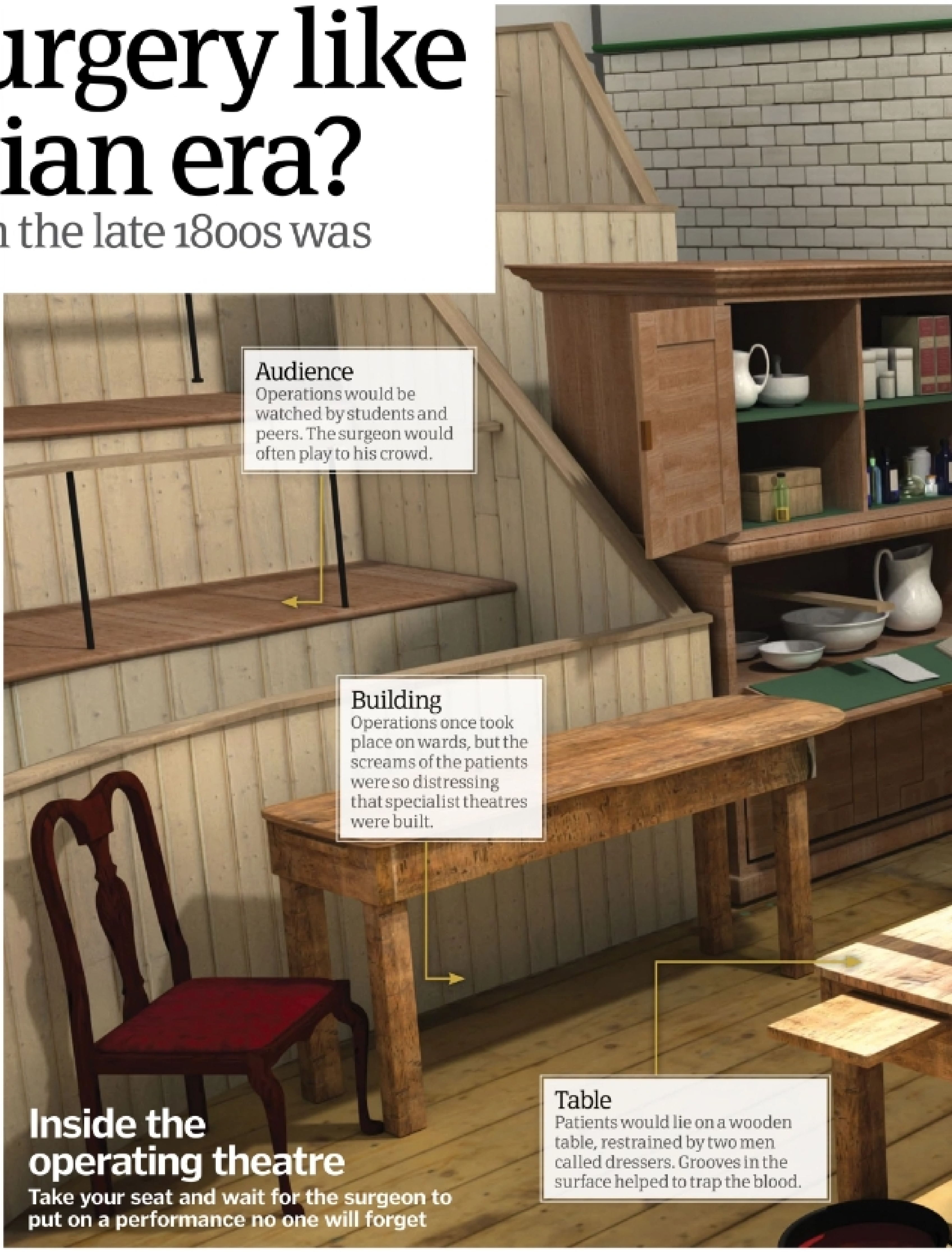
What was surgery like in the Victorian era?

Being a surgeon or patient in the late 1800s was not for the faint-hearted

The Victorian era has been romanticised for its advancements in science and medicine, but with that came no anaesthetic, poor sanitation and surgeons who didn't even need a qualification to operate. The risk of infection or bleeding to death was so high that surgery was limited to amputations. If you broke a limb, it would have to come off. The surgeon would often perform the procedure in a packed operating theatre, full of students and peers. Rusty saws and knives were the norm, as was the blood-encrusted apron that made the surgeon look more like a butcher than a man of medicine. He would slice through flesh and bone in 30 seconds flat. The faster the better, to prevent the patient from fleeing mid-way through, or worse, dying from shock.

Anaesthesia and painkillers weren't in use until the latter half of the 19th century, and even then they were very rudimentary. Alcohol was always an option, to get the patient drunk enough to numb the pain. Chloroform and ether were also used as early anaesthetics, but both were dangerously potent, and ether was also highly flammable – rather hazardous for use in theatres that were lit by naked flames.

One of the major advances in surgery was in 1867, when Joseph Lister pioneered aseptic techniques and began to sterilise wounds, operating theatres and instruments using carbolic acid. He even experimented with hand washing, which had previously only been performed *after* an operation. This lowered infection, and Lister eventually became known as the 'father of antiseptic surgery'.



Audience
Operations would be watched by students and peers. The surgeon would often play to his crowd.

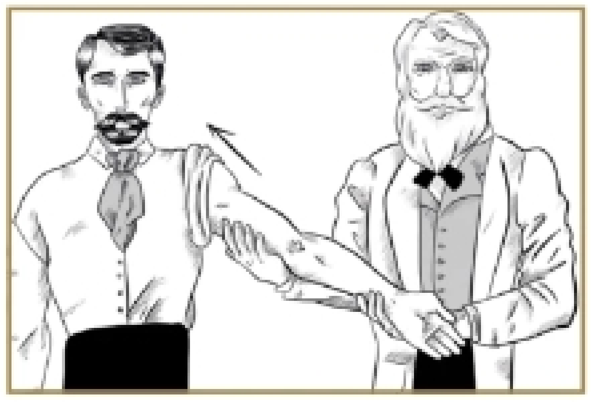
Building
Operations once took place on wards, but the screams of the patients were so distressing that specialist theatres were built.

Table
Patients would lie on a wooden table, restrained by two men called dressers. Grooves in the surface helped to trap the blood.

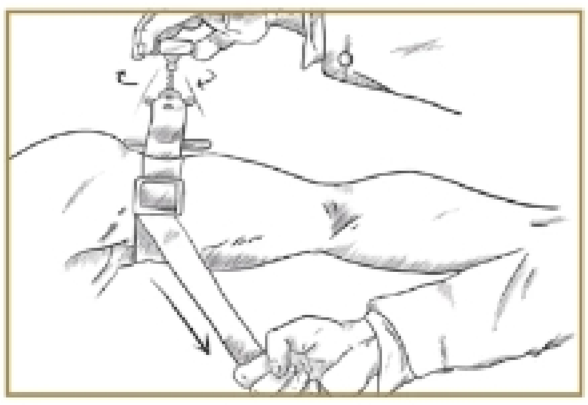
Inside the operating theatre

Take your seat and wait for the surgeon to put on a performance no one will forget

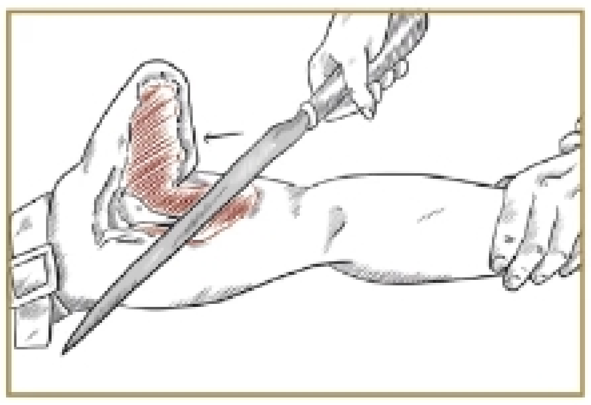
A step-by-step guide to amputation



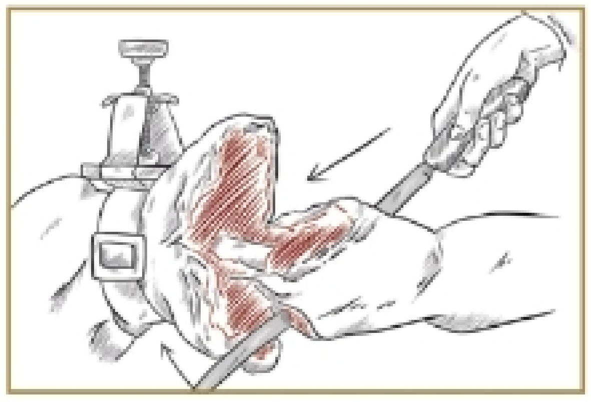
1 Prep the patient
Patients were laid on an operating table, and warned to keep very still, often without any anaesthetic or painkillers. The slightest movement could botch the operation and result in death.



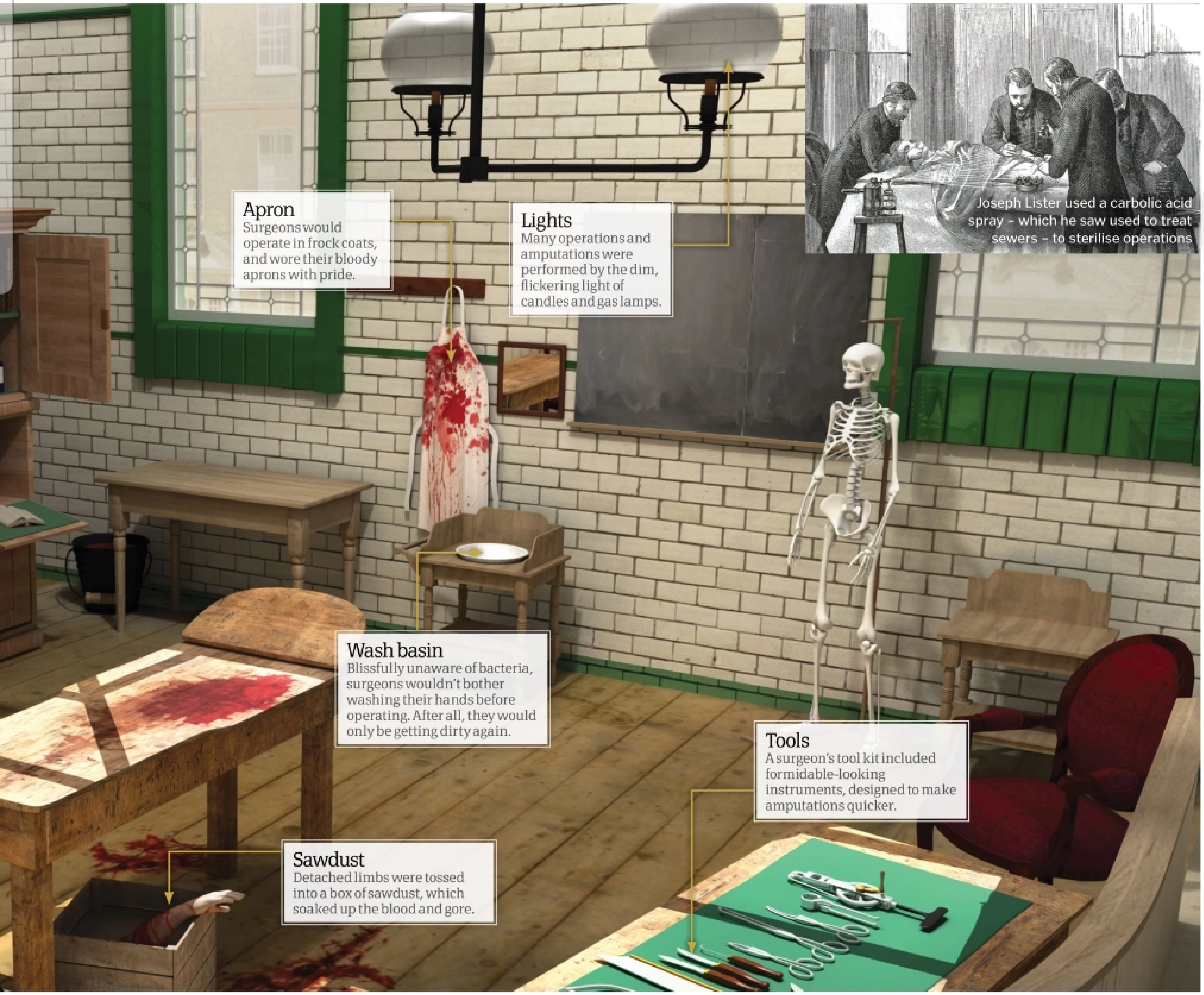
2 Tighten the tourniquet
To stem the flow of blood, tourniquets were placed above the incision. These were made of canvas straps that were tightened using a screw attached to brass plates on either side.



3 Make the first incision
Surgeons would use large knives, often with curved blades. The first incision would slice through the flesh and muscles that were around the bone in a circular motion.



4 Make the second incision
This process was then repeated on the other side of the limb. It was called the 'tour de maitre', or 'turn of the master', and it had to be performed very quickly for the patient's sake.



Joseph Lister used a carbolic acid spray – which he saw used to treat sewers – to sterilise operations

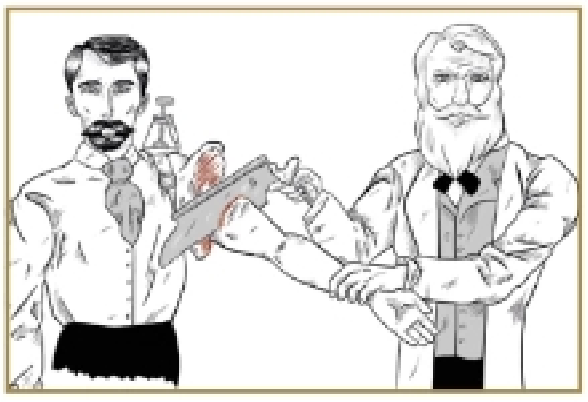
Apron
Surgeons would operate in frock coats, and wore their bloody aprons with pride.

Lights
Many operations and amputations were performed by the dim, flickering light of candles and gas lamps.

Wash basin
Blissfully unaware of bacteria, surgeons wouldn't bother washing their hands before operating. After all, they would only be getting dirty again.

Tools
A surgeon's tool kit included formidable-looking instruments, designed to make amputations quicker.

Sawdust
Detached limbs were tossed into a box of sawdust, which soaked up the blood and gore.

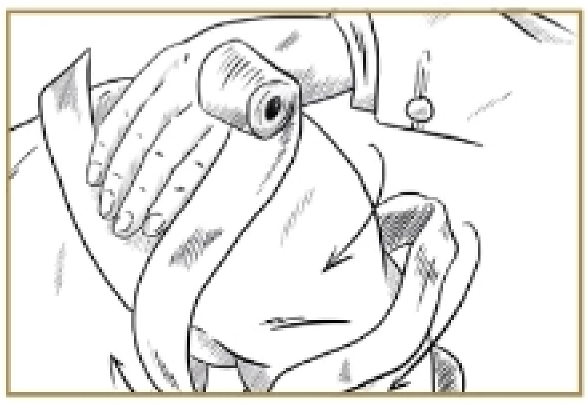


5 Saw the bone

Using the amputation saw, the surgeon would cut completely through the bone. The detached limb would then be dropped into a bucket of sawdust in order to absorb the blood.

6 Stitch it up

Once the limb was free, the surgeon would stitch up the main artery and smaller blood vessels. When the blood eventually stopped flowing, he would begin to stitch up the wound.



7 Bandage it up

The stump would be dressed in bandages. This had to be done carefully, because bandages that were either too loose or too tight could cause issues with the healing process.

8 Apply final touches

Once the procedure was finished, the patient would be taken away for recovery. Some 25 per cent of amputees would not survive, as poor sanitation often led to deadly infections.

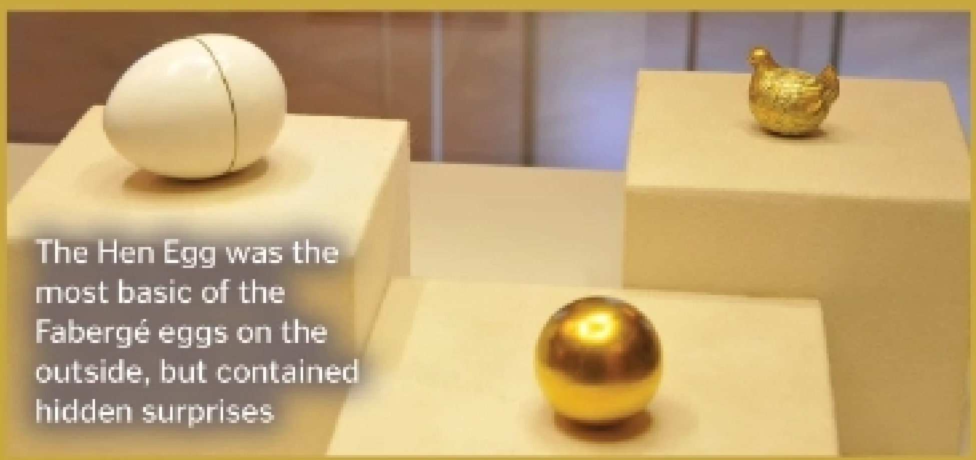
What is the significance of Fabergé eggs?

The fabulous history behind an incredibly lavish tradition

A beautiful example of 19th century Russian art, Fabergé eggs delighted the ruling Romanovs for over three decades. Created by jeweller Peter Carl Fabergé, they were given as gifts between members of the royal family. As time wore on, it became an ever-more extravagant tradition that symbolised royal excesses in the years leading up to the Russian Revolution. Some 50 of these Imperial Easter eggs were created, and each one could take up to a year to create. They were the project of not one, but a whole team of talented craftsmen. One of the most expensive was the diamond snowflake-encrusted 1913 Winter Egg; at a value of 24,600 roubles in 1913 it would cost an eye-watering £2.36 million today.

The eggs were designed around a different theme each year, but they all had an immaculately designed exterior with an intricate surprise lying inside. These ranged from mechanical swans to ivory elephants, and some were even powered by clockwork.

As political unrest escalated, Fabergé eggs were seen as a symbol of Romanov wastefulness. After the Bolshevik takeover, many of the eggs were confiscated and the Fabergé family fled Russia. Just 43 Imperial Easter eggs survive today and are owned by collectors, museums and monarchs. The British Royal Family own three of them, including the Mosaic Egg, which is decorated with a mesh of tiny gems, diamonds and pearls, and contains a miniature portrait of Tsar Nicholas II's children.



The Hen Egg was the most basic of the Fabergé eggs on the outside, but contained hidden surprises

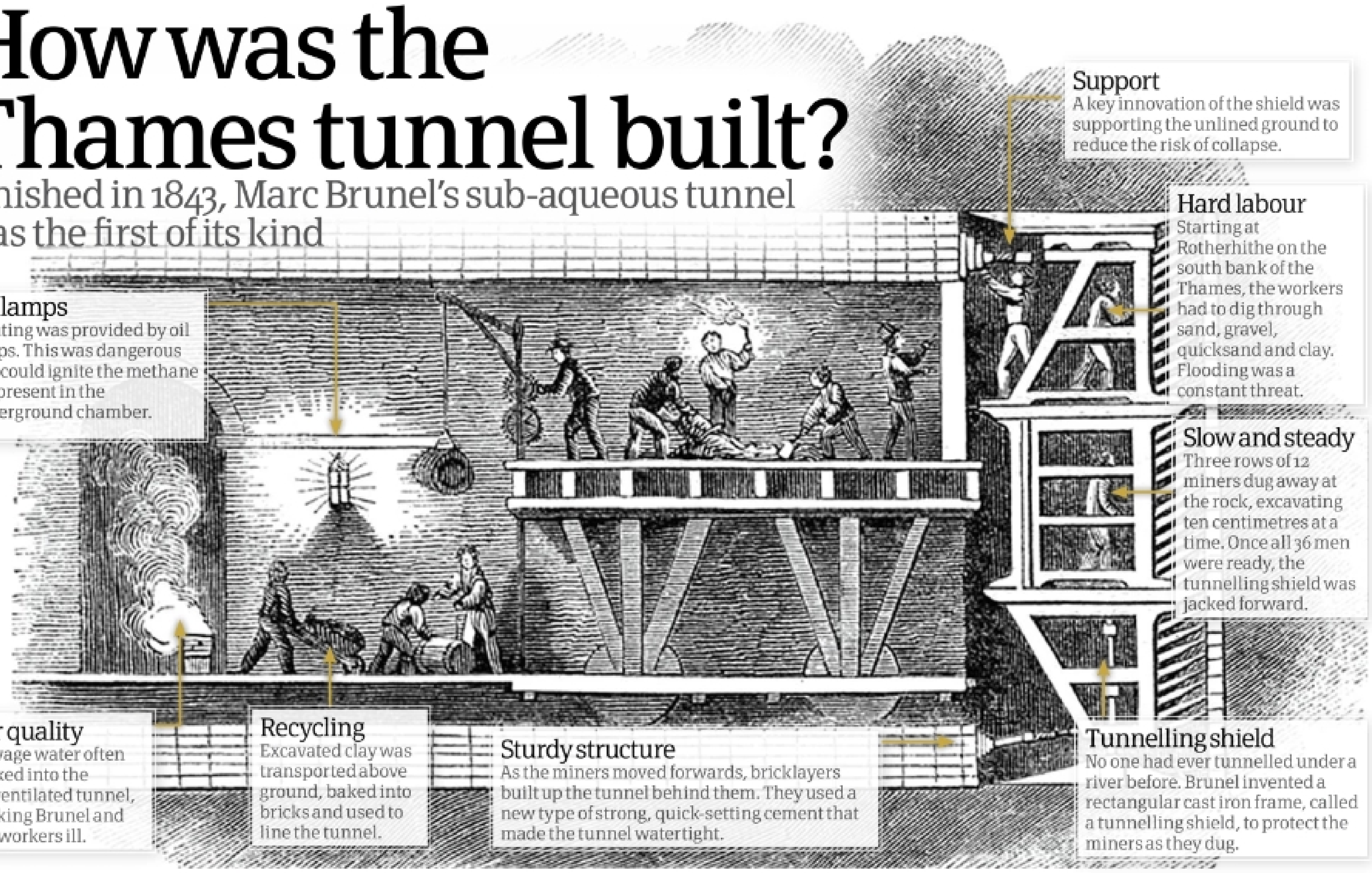
The first egg

In 1885 Russian Tsar Alexander III needed a present for his wife, Empress Marie Fedorovna. He decided on a jewel-encrusted egg – and began a royal family tradition in the process. Known as the Hen Egg, this first gift appeared relatively simple from the outside, but opened to reveal a golden chicken, which contained a tiny ruby egg pendant and a miniature diamond crown. The Empress was thrilled with her gift and Peter Carl Fabergé was given complete control of all future eggs' designs, with the only prerequisite being that a surprise was hidden within the shell. They continued to be popular gifts under both Alexander and his son Nicholas II.

© Alamy

How was the Thames tunnel built?

Finished in 1843, Marc Brunel's sub-aqueous tunnel was the first of its kind



Support
A key innovation of the shield was supporting the unlined ground to reduce the risk of collapse.

Hard labour
Starting at Rotherhithe on the south bank of the Thames, the workers had to dig through sand, gravel, quicksand and clay. Flooding was a constant threat.

Slow and steady
Three rows of 12 miners dug away at the rock, excavating ten centimetres at a time. Once all 36 men were ready, the tunnelling shield was jacked forward.

Oil lamps
Lighting was provided by oil lamps. This was dangerous as it could ignite the methane gas present in the underground chamber.

Air quality
Sewage water often leaked into the unventilated tunnel, making Brunel and his workers ill.

Recycling
Excavated clay was transported above ground, baked into bricks and used to line the tunnel.

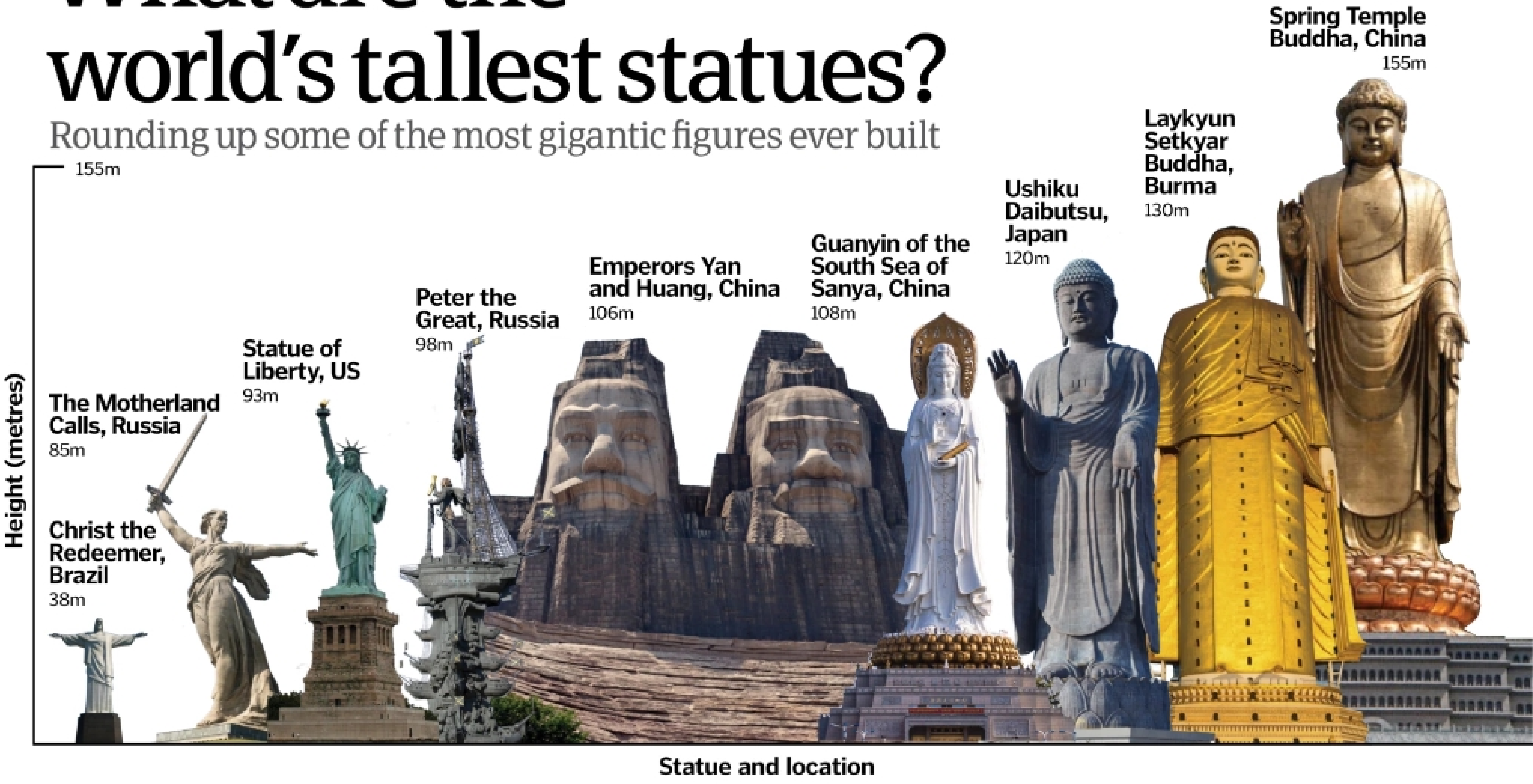
Sturdy structure
As the miners moved forwards, bricklayers built up the tunnel behind them. They used a new type of strong, quick-setting cement that made the tunnel watertight.

Tunnelling shield
No one had ever tunnelled under a river before. Brunel invented a rectangular cast iron frame, called a tunnelling shield, to protect the miners as they dug.

© Thinkstock, Dreamstime

What are the world's tallest statues?

Rounding up some of the most gigantic figures ever built



What was the biggest sloth?

One of the biggest land mammals that ever existed, the giant ground sloth roamed the Earth for millions of years

Towering over the Cenozoic flora of South America, a sloth the size of an elephant stomps across the wilderness. Megatherium – or the giant ground sloth – was one of many megafauna species to roam prehistoric Earth and could grow to around six metres in length from head to tail. Unrecognisable from their modern-day relatives, these ground sloths only had to stand on their hind legs to reach the treetops.

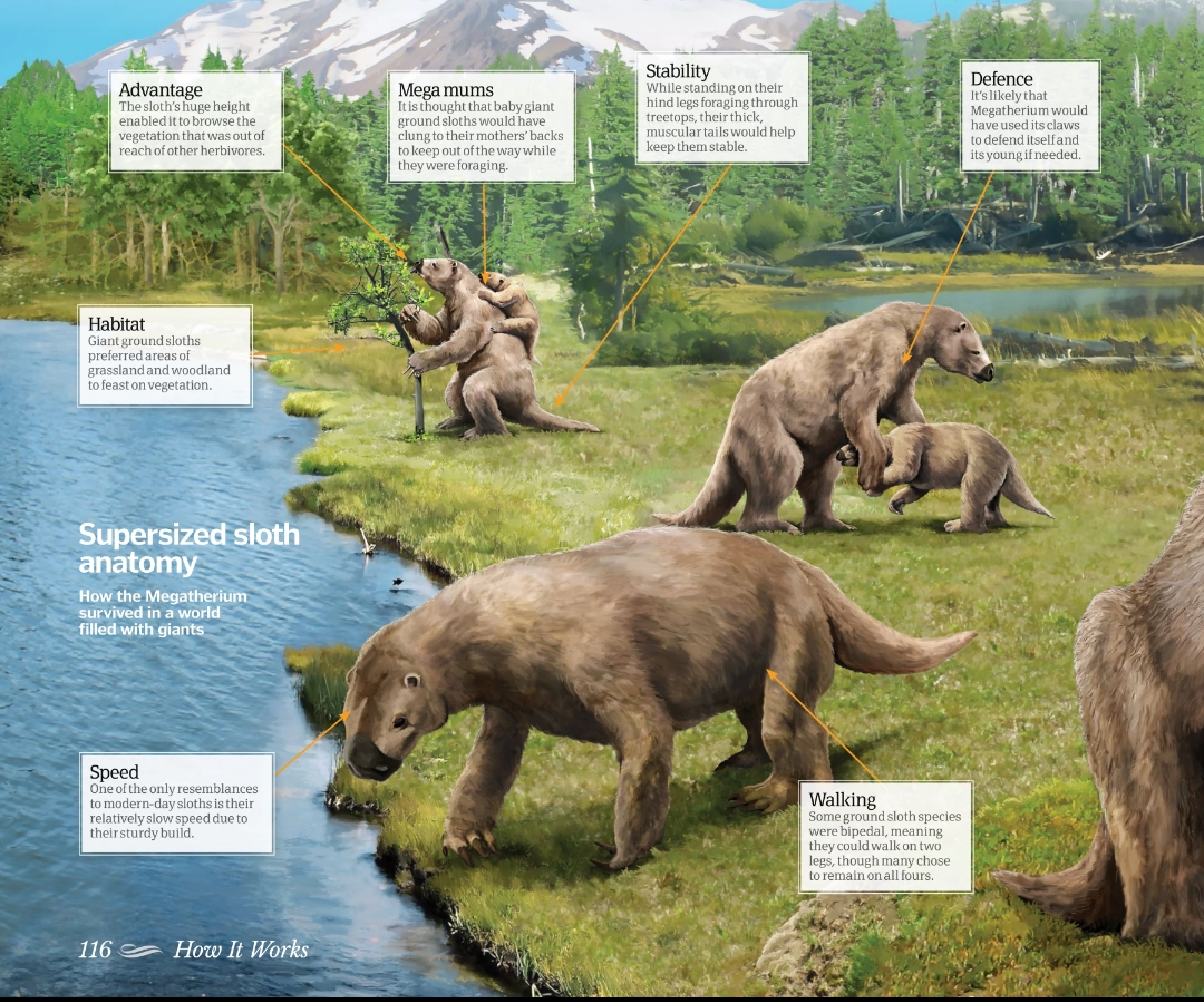
The Megatherium's elongated claws led biologists to once believe that these giants not only feasted on leafy greens but also the flesh of other animals. However, after analysing the collagen in their fossil remains, it was revealed that these mighty mammals were in fact herbivores and most likely used their long curved claws to grasp onto vegetation.

It wasn't until the Isthmus of Panama (a narrow strip of land formed by the growth of volcanic islands and tectonic activity) bridged the gap between North and South America – separating the Atlantic and Pacific oceans in the process – approximately 3 million years ago that the Megatherium and other South American megafauna could migrate north.

It's estimated that giant sloths evolved during the Eocene and existed for nearly 35 million years before facing extinction at the end of the last ice age around 11,700 years ago. Many large mammal species started to go extinct at around this time, including woolly mammoths, sabre-toothed cats and dire wolves . The prevailing theory is that the megafauna extinction was the combined result of climate change and human hunting.

Supersized sloth anatomy

How the Megatherium survived in a world filled with giants



Advantage
The sloth's huge height enabled it to browse the vegetation that was out of reach of other herbivores.

Mega mums
It is thought that baby giant ground sloths would have clung to their mothers' backs to keep out of the way while they were foraging.

Stability
While standing on their hind legs foraging through treetops, their thick, muscular tails would help keep them stable.

Defence
It's likely that Megatherium would have used its claws to defend itself and its young if needed.

Habitat
Giant ground sloths preferred areas of grassland and woodland to feast on vegetation.

Speed
One of the only resemblances to modern-day sloths is their relatively slow speed due to their sturdy build.

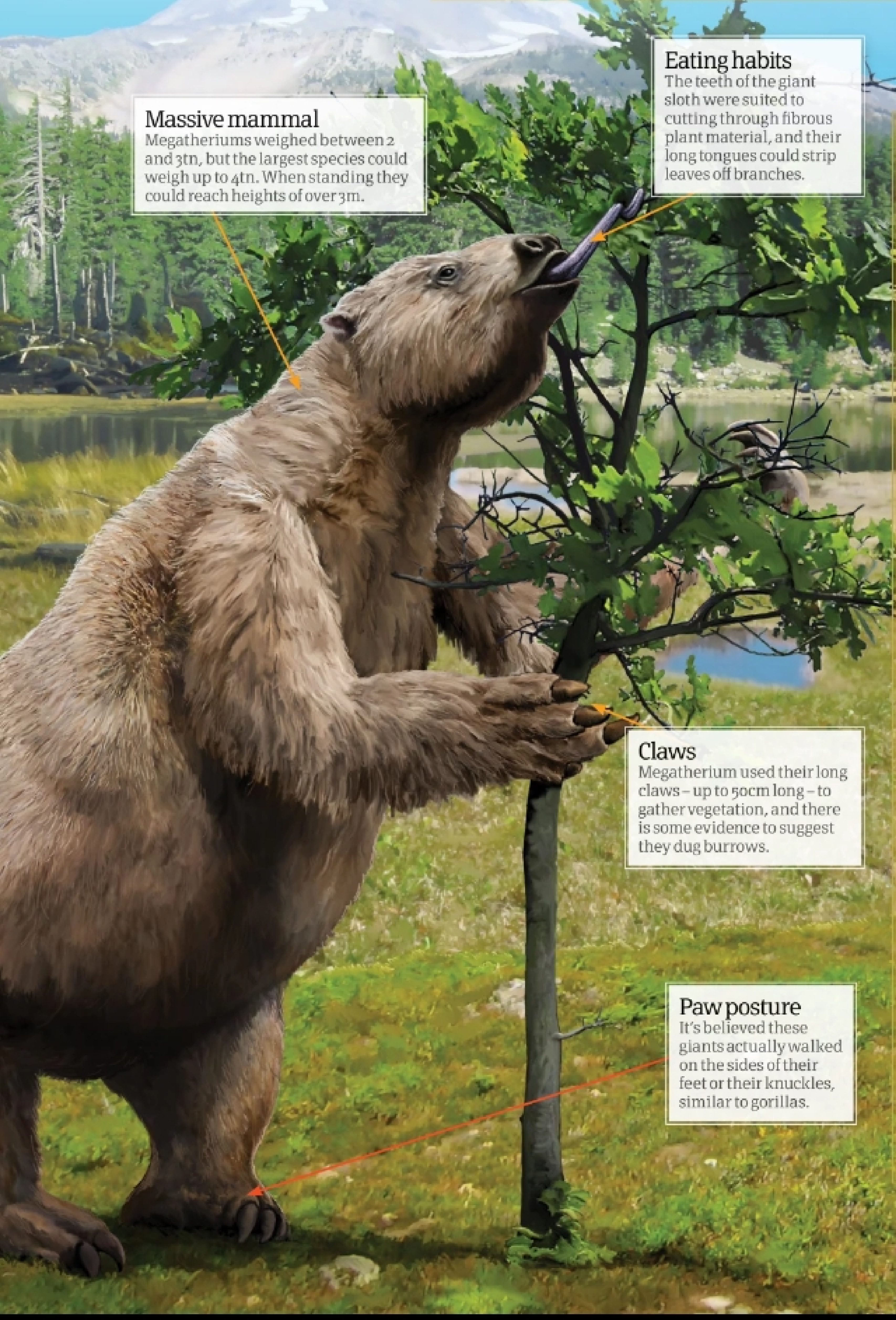
Walking
Some ground sloth species were bipedal, meaning they could walk on two legs, though many chose to remain on all fours.

Battling behemoths

It is still not completely clear what caused the Quaternary extinction event that led to the eradication of all prehistoric megafauna around 10,000 years ago. However, it's safe to say that human hunting played its part. But how did our comparatively small ancestors go toe-to-claw with prehistoric giants? Confronting these giants armed with massive claws and tusks presented dangers to both man and beast.

Earlier this year, palaeontologists discovered a set of fossilised ground sloth tracks that appeared to have a collection of human footprints stalking it. Though no remains of a successful hunt where found near the tracks, it seems that our ancestors may have hunted by ambushing their prey rather than tackling it head-on.

Prehistoric hunters may have laid in wait to ambush giant mammals


Massive mammal
Megatheriums weighed between 2 and 3tn, but the largest species could weigh up to 4tn. When standing they could reach heights of over 3m.

Eating habits
The teeth of the giant sloth were suited to cutting through fibrous plant material, and their long tongues could strip leaves off branches.

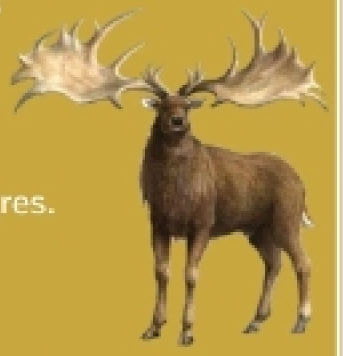
Claws
Megatherium used their long claws – up to 50cm long – to gather vegetation, and there is some evidence to suggest they dug burrows.

Paw posture
It's believed these giants actually walked on the sides of their feet or their knuckles, similar to gorillas.

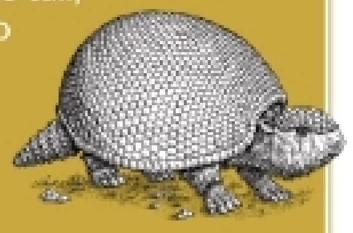
5 facts about other mighty megafauna

1 **Moa**
These large birds were completely flightless, void of any wing bones. Some members of the many species of moa stood at three metres tall.

2 **Irish elk**
Mistakenly named an elk, this giant deer was in fact one of the largest of its kind to ever exist. Specimens could reach over two metres from hoof to shoulder, with antlers that could span more than 3.5 metres.



3 **Glyptodon**
Weighing about one ton and measuring three metres nose to tail, this heavily armoured armadillo ancestor was covered in bony scutes for protection against predators.



4 **Diprotodon**
The largest marsupial to have ever lived roamed across the plains, woodlands and savannahs of prehistoric Australia. These two-metre-tall, four-metre-long wombats weighed approximately three tons.

5 **Mammoth**
These extinct elephants could reach epic proportions. The woolly mammoth was roughly the size of the modern-day African elephant, but the Steppe mammoth could reach 4.5 metres in height.

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How do fossils form?

Discover life forms that lived millions or billions of years ago before being turned to stone

Extinction is a fact of life that, sooner or later, spells the end for all species. But dead doesn't mean forgotten. The evidence might have remained hidden for millions or even billions of years but, in the fifth century BCE, Greek philosopher Xenophanes discovered the fossils of sea creatures and recognised what they were.

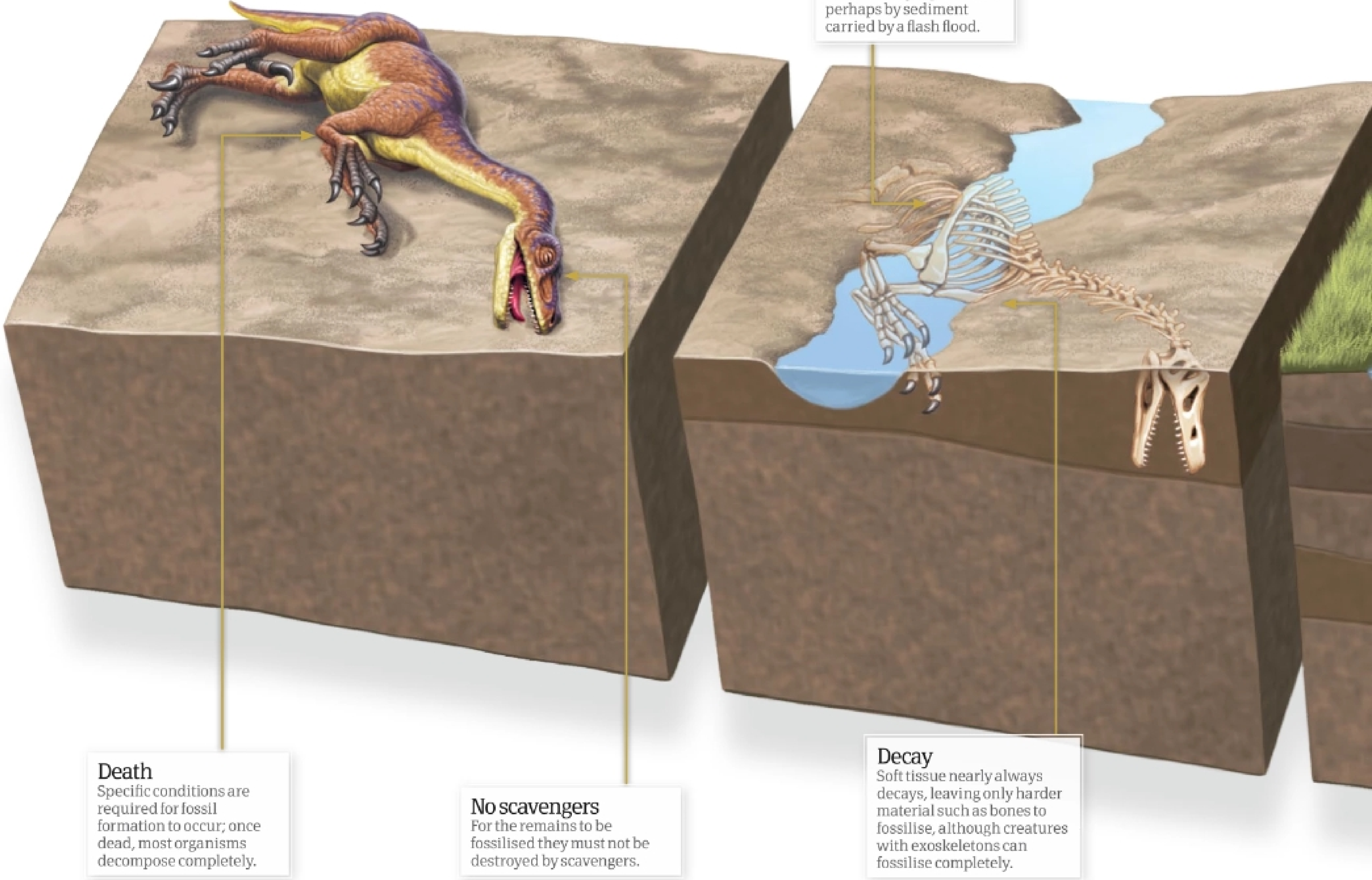
We'll look at exactly how it happens later, but put simply, a fossil was a living organism, which, following its death, turned to stone. And these records can teach us so much. Having found marine fossils on land, for example, Xenophanes was able to say with confidence that the sea once covered what was then dry land. Over the years, fossils have taught us a great deal about Earth's history, and the discoveries continue today.

For example, recent discoveries of fossils dating back to the dawn of our planet, when the Earth was an apparently inhospitable place, have fuelled speculation that life could have started on Mars at about the same time.

Mention fossils and many people think instantly of dinosaurs. These huge lizards might have left some of the largest, most impressive fossils, but they are not nearly the oldest, nor do they have a monopoly on providing a spectacle. The world of fossils is a varied one encompassing wonders as extraordinary as trilobites: large woodlouse-like creatures that crawled on the bed of tropical seas; brightly coloured petrified wood from long lost forests in Arizona; and coprolite – fossilised droppings.

The formation of fossils

How a living organism can be turned into stone and preserved for millions of years



Death
Specific conditions are required for fossil formation to occur; once dead, most organisms decompose completely.

No scavengers
For the remains to be fossilised they must not be destroyed by scavengers.

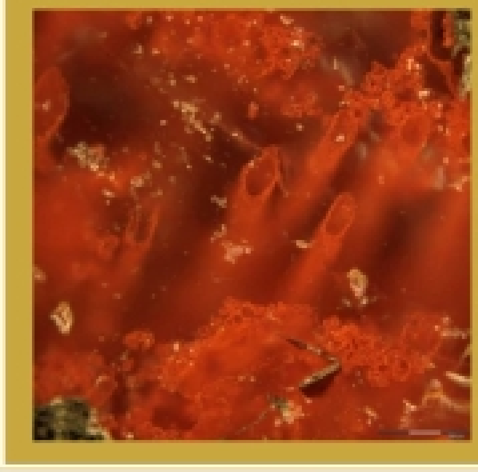
Burial
Protection of the remains is assisted by rapid burial, perhaps by sediment carried by a flash flood.

Decay
Soft tissue nearly always decays, leaving only harder material such as bones to fossilise, although creatures with exoskeletons can fossilise completely.

Top five fossil discoveries

The oldest fossils

Scientists at UCL have announced the oldest fossils yet. The tube-like structures, found in Canada, are about 3.77 billion years old and grew around deep-sea vents.

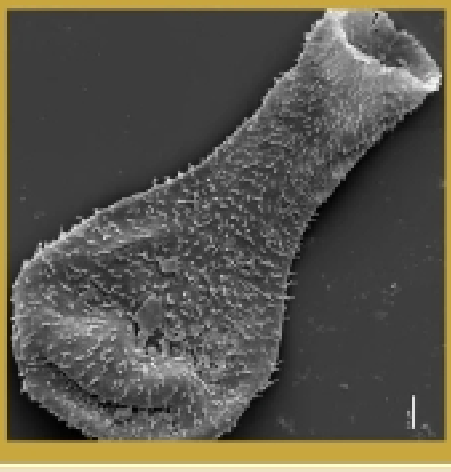


The largest fossil

Fossilised bones from Argentina represent the largest known dinosaur. The titanosaur was nearly 40 metres long, stood 20 metres tall, and weighed about 70 tons.

The smallest fossils

Not all fossils are massive; some are so small you need a microscope to see them. Marine microfossils known as Chitinozoa, for example, can be as little as 0.05mm long.

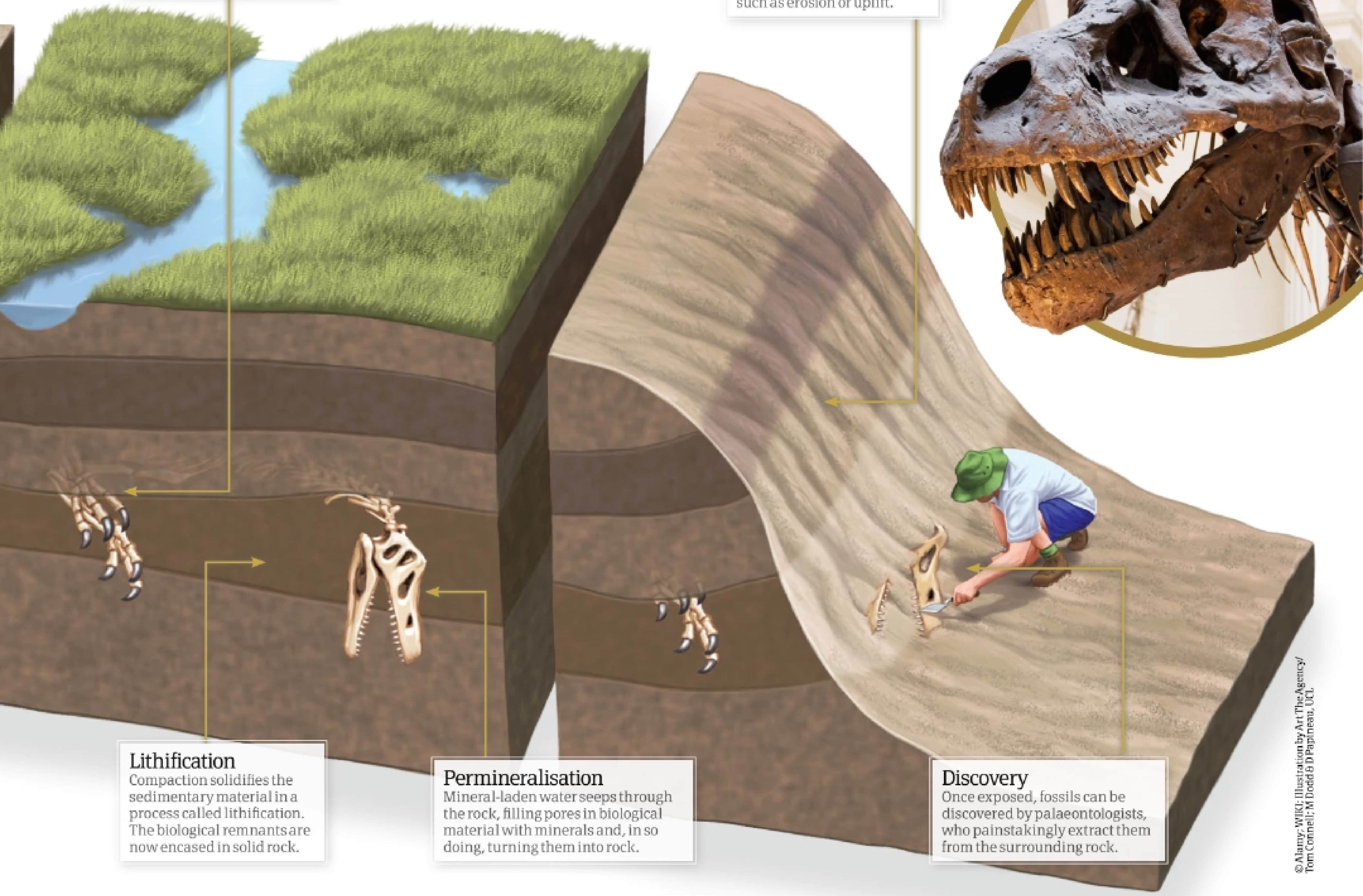


The rarest fossils

Soft tissue usually decays before fossilising, so fossils of creatures with no hard parts are rare. However, researchers at Berlin Free University recently found octopus fossils.

The family tree

Hominin fossils, such as the famous Lucy specimen, have enabled scientists to study human evolution. These findings have helped to shed light on our ancient cousins.



Deeper burial
Over time, geological events deposit more sediment, so the remains become buried to ever-greater depths.

Exposure
Although formed deep in the Earth, fossils can be exposed due to geological processes such as erosion or uplift.

Lithification
Compaction solidifies the sedimentary material in a process called lithification. The biological remnants are now encased in solid rock.

Permineralisation
Mineral-laden water seeps through the rock, filling pores in biological material with minerals and, in so doing, turning them into rock.

Discovery
Once exposed, fossils can be discovered by palaeontologists, who painstakingly extract them from the surrounding rock.

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How were hieroglyphics finally decoded?

Hieroglyphics proved difficult to work out, despite hundreds of years worth of attempts. The Rosetta Stone, discovered in the city of Rashid (Rosetta), Egypt, in 1799, provided final clues. The stone's text was in two languages but three scripts: Greek, hieroglyphic and demotic (a cursive hieroglyphic-based script that came after hieroglyphics). Scholar Jean-François Champollion spent years studying others' works and ancient Egyptian writings, as well as the Rosetta Stone. He could read Greek and Coptic, the final form of Ancient Egyptian script that used the Greek alphabet and seven demotic letters. Champollion decoded hieroglyphics by figuring out how the demotic signs were used in Coptic, then tracing them to their meaning in hieroglyphics. He published his findings in 1822, but it took further study for scholars to confidently read hieroglyphics.

© Dreamstime

Why do British monarchs have two birthdays?

In true British style, the reason for a British monarch having two birthdays is due to the weather. To mark the occasion, official celebrations are held on a Saturday in late May or June, as the weather is likely to be sunny. This is because birthday celebrations involve lots of outdoor activities, such as the Trooping the Colour military parade.

The tradition dates back to the 18th century when the annual summer military cavalcade became a celebration of King George II, as well as the armed forces – but his birthday was at the end of the year in chilly November. Since then, the official birthday of a monarch has been held during the summer.

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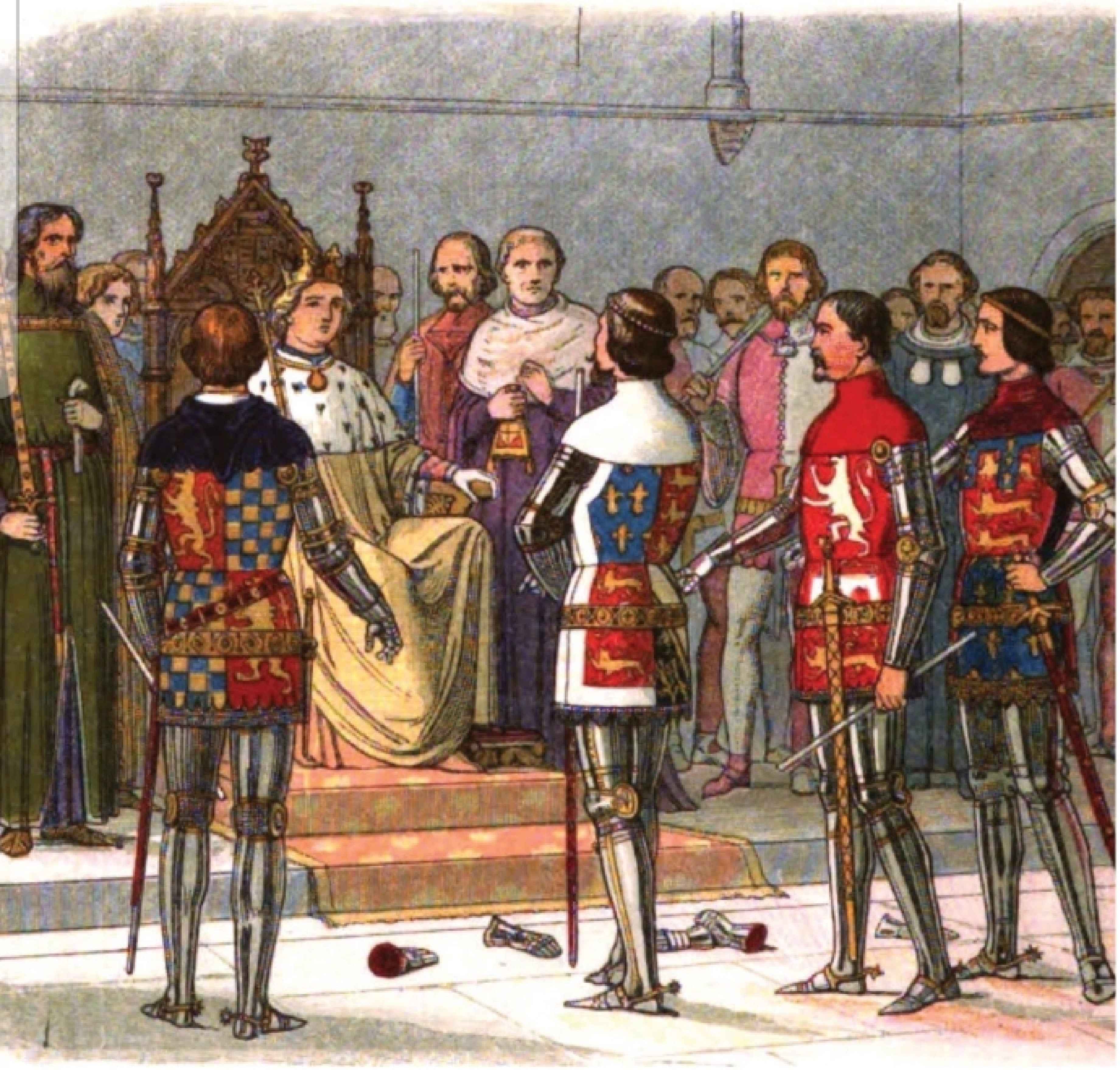
What is the Holy Grail?

The Holy Grail is a Christian legend expressed in Western European literature and art. The Grail itself is considered the most sacred Christian relic, most commonly said to be the cup from which Jesus drank at the last supper, and in which Joseph of Arimathea collected Jesus's blood at the crucifixion. Joseph of Arimathea is said to have then taken the cup to England, where it was hidden for hundreds of years. The knights of King Arthur made it their principal quest to find the cup because, according to the legend, it had special powers.

What happened to the Venus de Milo's arms?

Most scholars believe the arms of this Ancient Greek sculpture were already missing when it was found, but some believe they were broken off in a fight in 1820. Venus is also missing her left foot, headband and metal jewellery.



Where does the saying 'throw down the gauntlet' come from?

To a Medieval knight a gauntlet was a sort of armoured glove worn to protect the hands from injury as part of their suit of armour. Violence was often used to settle disagreements in the Middle Ages, and one knight could challenge another to fight a duel by taking off his gauntlet and throwing it to the floor in front of his rival. 'Throwing down the gauntlet' was both an insult and a challenge. A knight would risk dishonour and humiliation if he refused to accept such a challenge, or 'take up the gauntlet', another saying which is still with us today.

> "Throwing down the gauntlet was both an insult and a challenge"

When did the white flag become associated with surrender?

Surrendering with the white flag is at least as old as China's Han Dynasty, dating back to 25 to roughly 225 CE. However, it probably began even earlier. Roman historian Cornelius Tacitus also wrote about them in 109 CE, referencing white-flag use in a battle that took place about 40 years earlier.

White fabric was probably used because it was the easiest colour of material to obtain, and it also stood out against the landscape and the other more colourful flags on the battlefield.

Today using a white flag as a symbol of ceasefire, surrender or negotiation is part of the Geneva Convention.

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Why did civilisations stop building city walls?

Defensive walls were built as a barrier and a lookout point. They were useful for thousands of years, but as weaponry improved, and as people took to the air, it became easier to breach these defences. Populations also expanded, and it became less practical to keep everyone enclosed inside a physical barrier.

However, although most settlements are not hidden behind walls today, people have not stopped building them. Patrolled border fences control the flow of people between countries, walls are used to mark out gated communities, and in regions of conflict they are erected as barriers to separate the two opposing sides.

© Dreamstime

Why are American soldiers called GIs?

The reason behind this name is not totally clear, but the most widely believed theory dates back to the beginning of the 20th century, when the letters 'GI' were stamped on military trash cans and buckets to show they were made of galvanised iron. The theory goes that it was then used to refer to all things related to the army in World War I, but the meaning of the letters changed to 'government issue' or 'general issue'. By the time World War II occurred, soldiers were referring to themselves as GIs. US toy company Hasbro created the popular GI Joe doll in 1964, and the nickname has stuck ever since.

Why did the Egyptians build the Great Sphinx?

Sphinx statues were built in Ancient Egypt to guard important areas. The Great Sphinx of Giza is thought to have been built during the reign of Pharaoh Khafre, between 2520 and 2494 BCE. There was a trend for large stone architecture, but instead of using stone blocks, the Great Sphinx was carved out of a single, enormous mass of limestone. It's believed to be part of a set of structures that were built to associate the dead king with the Sun god.

© Therightclicks

How did the bald eagle become America's national bird?

Soon after the Declaration of Independence was signed on 4 July 1776, Benjamin Franklin, Thomas Jefferson and John Adams were tasked with designing an official seal for the new nation. Years later, after disapproval of the designs by the Continental Congress, Secretary of Congress Charles Thomson combined the best elements of the designs he'd seen.

The eagle had initially been introduced by lawyer William Barton. Thomson decided to make it a prominent feature and turned it into an American bald eagle, a symbol of strength and native to the US. The design was adopted by Congress on 20 June 1782 and the bald eagle soon became America's national bird and a symbol recognised worldwide..

Why aren't pterodactyls classed as dinosaurs?

It seems that we have oversimplified the naming conventions for prehistoric creatures. 'Pterodactyl' is the informal name for winged reptiles, properly known as pterosaurs. These flying creatures lived among dinosaurs from the Triassic to the Cretaceous period but weren't actually classified as dinosaurs.

The two groups have a shared common ancestor, but diverged to evolve unique characteristics which ultimately separated them. Modern birds are likely to be descended from small, feathered, land-based dinosaurs, not pterosaurs – or pterodactyls, for that matter.

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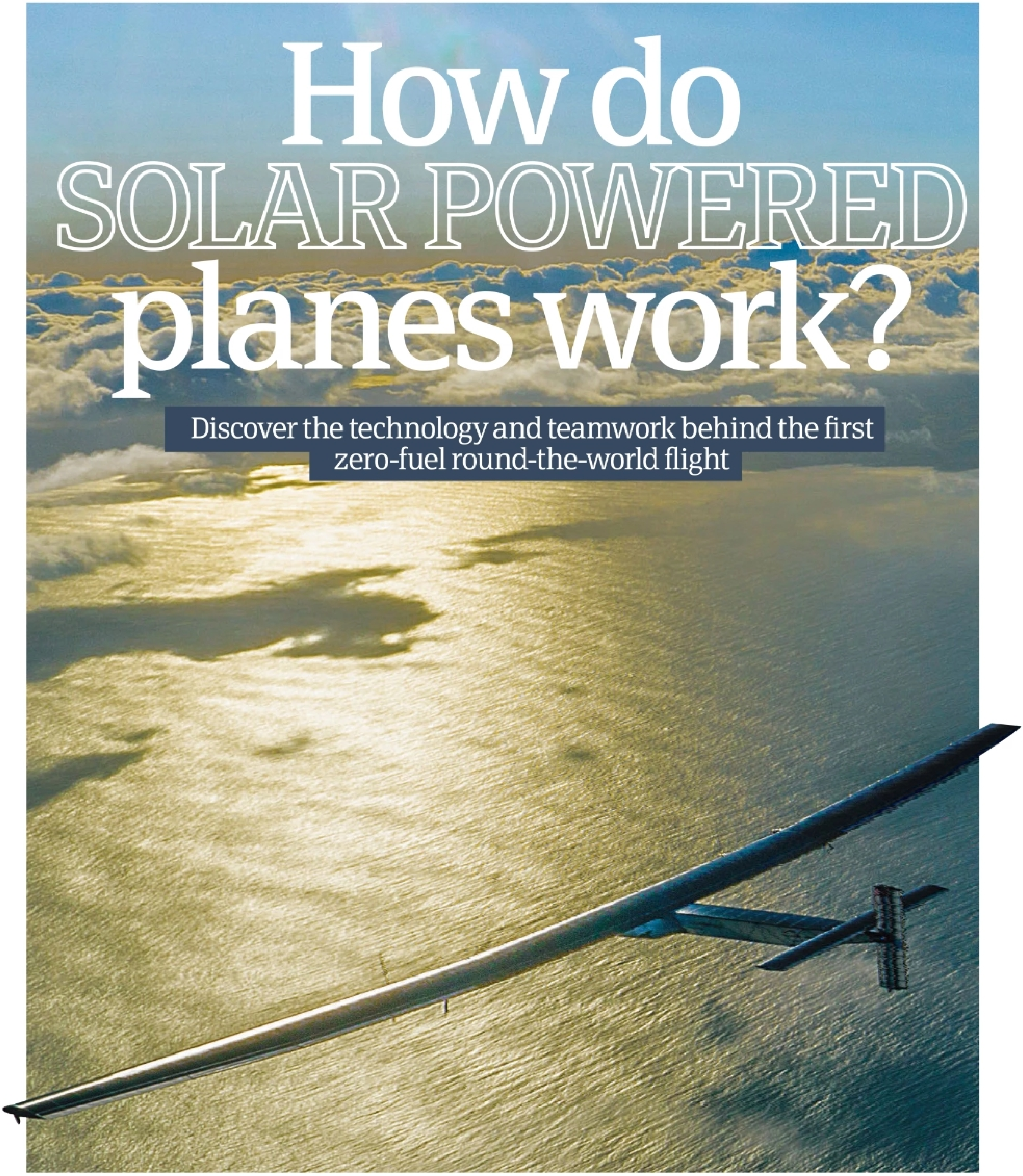
Transport

126 How do solar-powered planes work?
130 Will rockets replace planes?
134How do gliders stay airborne?
135 What are shipping lanes?
135 How do cat's eyes work?
136 Why do leaves on the line affect trains?
136How do wingsuits work?
137 How does the Sailrocket 2 work?
138 How do trams work?
138 How do you balance on a unicycle?
139 What makes up a road?
139 How do trains change tracks?
140 Bitesize Q&A

How do SOLAR POWERED planes work?

Discover the technology and teamwork behind the first zero-fuel round-the-world flight



In July 2010, the experimental aircraft Solar Impulse took to the skies. While it was not the first solar-powered plane, the team behind the Solar Impulse project had achieved a historic feat – they had harnessed the power of the Sun to perform a 26-hour flight, including nine hours overnight. This prototype set eight world records, but it was soon eclipsed by its successor.

The Solar Impulse 2 (Si2) was completed in 2014, built to perform the first zero-fuel circumnavigation. Si2 exceeded all expectations and flew around the world in a 17-leg journey that took 558 hours and seven minutes in total. The team covered over 43,000 kilometres at an average speed of 75 kilometres per hour, all with no fuel.

Aviation is responsible for more than two per cent of the world's carbon emissions, so the pressure is on to reduce the amount of fossil fuels being used. Engineers and scientists are currently exploring a range of options, but with concerns surrounding hydrogen fuel safety and with biofuels yet to break into the aviation sector, some manufacturers have set their sights on solar power.

Just like with domestic solar roof panels, Si2 uses devices called photovoltaic cells, or solar cells, to generate electricity from sunlight. These cells are very thin and made with silicon, which is a semiconductor – a material that can conduct electricity while acting like an insulator. When photons of sunlight hit a cell, it forces electrons to move from one side of the silicon wafer to the other. This flow of electrons creates a current, generating electricity that can be harnessed by an attached circuit. Si2 has over 17,000 of these cells installed across its surface. The electricity that is generated powers the plane's motors (which turn the propellers) and also charges the onboard batteries for flying at night.

Solar Impulse sought to push the boundaries, not just to set a world record but to prove that this technology could be a viable option for the future of flight. CEO, co-founder and pilot André Borschberg said in a statement, "Flying around the world is a real challenge. More than a demonstration, it's the confirmation that these technologies are truly dependable and reliable."

Borschberg and his fellow pilot Bertrand Piccard were no strangers to big challenges.

Each leg of the flight was carefully planned and scheduled to make the most of optimal weather conditions

Pilot Bertrand Piccard takes a selfie during flight in Solar Impulse 2

To infinity and beyond

Despite the breakthroughs made by the Solar Impulse, there is scepticism about how viable the technology could be for commercial planes.

There is some doubt that the crafts could sustain sufficient power to carry as many passengers as current commercial models. A Boeing 747-400 can transport over 300 passengers at a cruising speed of about 910 kilometres per hour. In contrast, the Solar Impulse is the same width but is only able to carry a single passenger at an average speed of 75 kilometres per hour.

This would lengthen a flight from London to New York from 7.5-hours to over three days, assuming that the solar aircraft would be at top speed for the entire transatlantic crossing.

Adventurer Piccard set a record when he completed the first ever non-stop balloon flight around the world in 1999, while ex-Swiss Air Force pilot Borschberg had already faced his own run-ins with danger, surviving a helicopter crash and an avalanche accident. Their circumnavigation project would face technical issues and poor flying conditions, but the combined skills and experience of the pilots and the Solar Impulse team ensured the journey was a success.

While it has the wingspan of a Boeing 747 jet, it only weighs as much as a family car, so strong winds during take off or landing would easily blow it off course. In order for a flight to commence, a combination of battery power and solar energy first have to start to turn the propellers. Then with its nose titled up, the lightweight craft smoothly ascends into the air.

It rises slowly, past the turbulent jet stream at 35,000 feet (10,668 metres) up into the clouds. The pilot must skilfully dodge any dense clouds that will otherwise block the all-important sunlight from reaching the solar panels. To turn the plane, a propeller on one side of the wings speeds up. The solar panels charge the plane's batteries during the day, with the plane climbing to 28,000 feet (8,534 metres) and gliding to 5,000 feet (1,524 metres) to conserve energy at night. When it is time to land, the power to the propellers is shut off and the craft glides back down to terra firma.

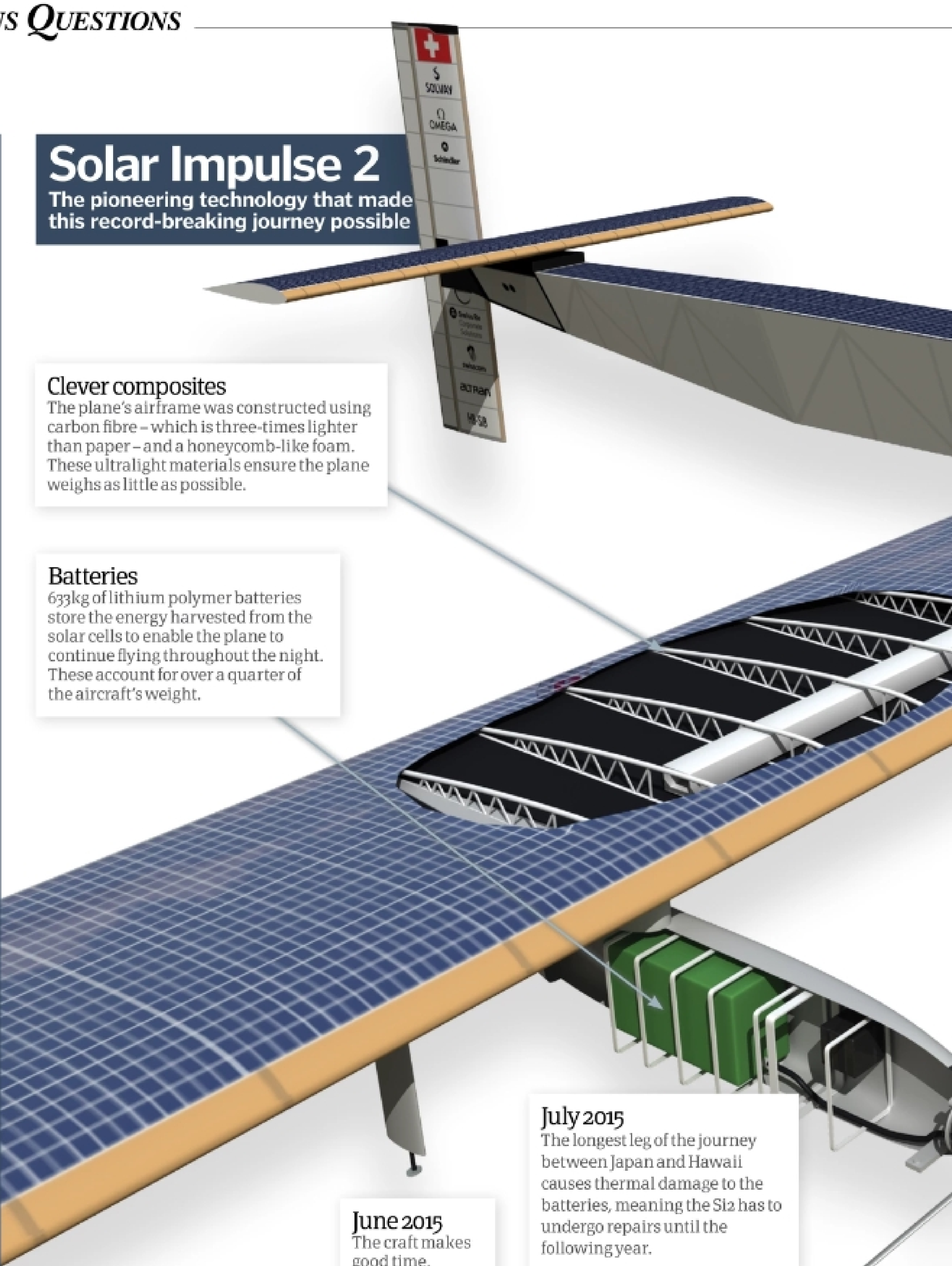
The two pilots alternated between each leg of the flight. They started in Abu Dhabi before travelling eastward across Asia, crossing the Pacific, the US, the Atlantic and Europe before finally returning to Abu Dhabi. The longest journey was the Pacific crossing, completed in 117 hours and 52 minutes.

So is this the future of green technology? We still have a long way to go, but it's not unrealistic to imagine that within the next few decades we could be using solar-powered planes commercially. Solar Impulse exceeded all expectations, proving just how much we can achieve already.

After landing at the final stop on this journey, Bertrand Piccard addressed the waiting crowd: "This is not only a first in the history of aviation; it's before all a first in the history of energy. I'm sure that within ten years we'll see electric airplanes transporting 50 passengers on short- to medium-haul flights. Solar Impulse is only the beginning. Now take it further!"

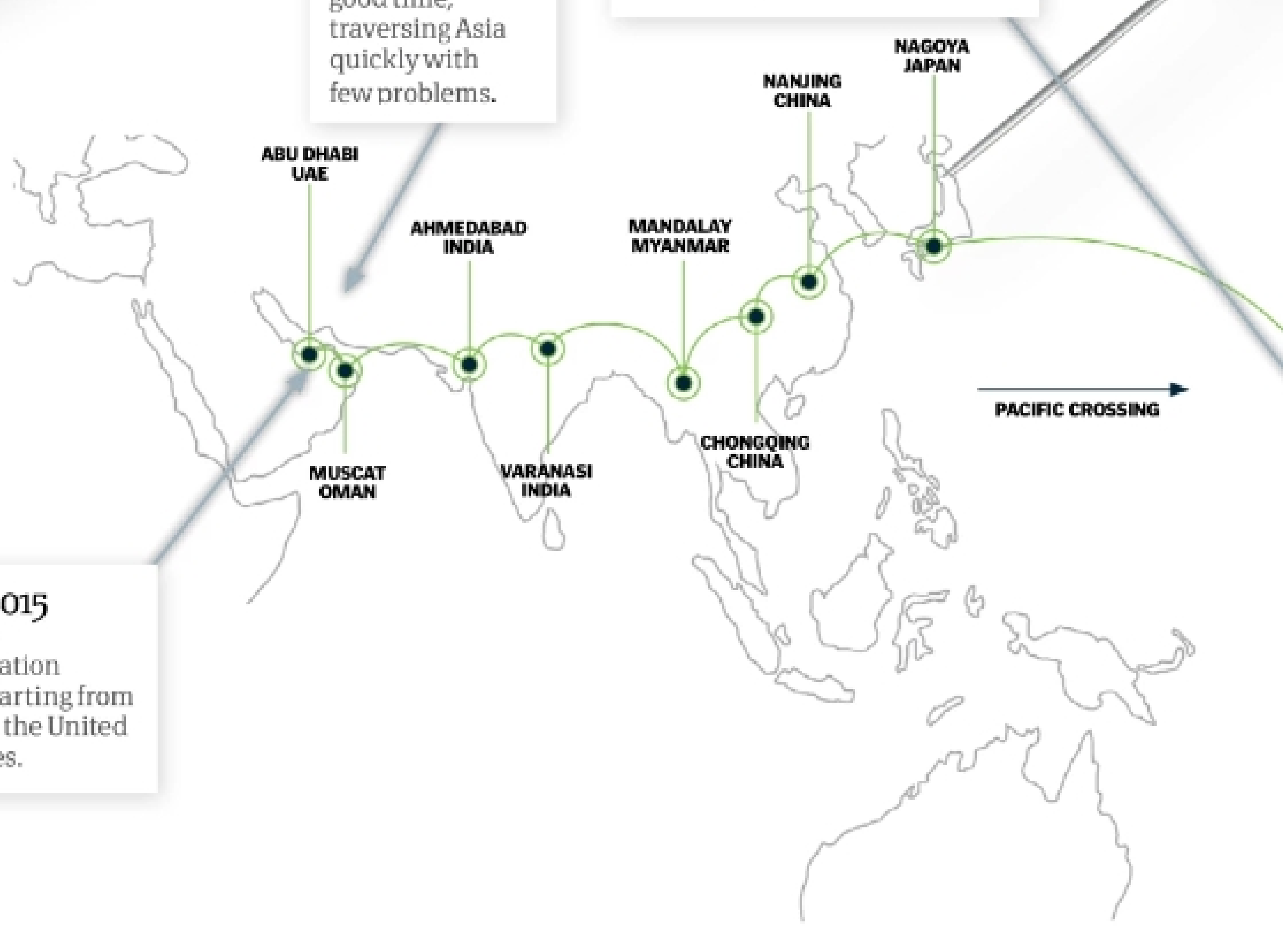
Solar Impulse 2

The pioneering technology that made this record-breaking journey possible



Clever composites
The plane's airframe was constructed using carbon fibre – which is three-times lighter than paper – and a honeycomb-like foam. These ultralight materials ensure the plane weighs as little as possible.

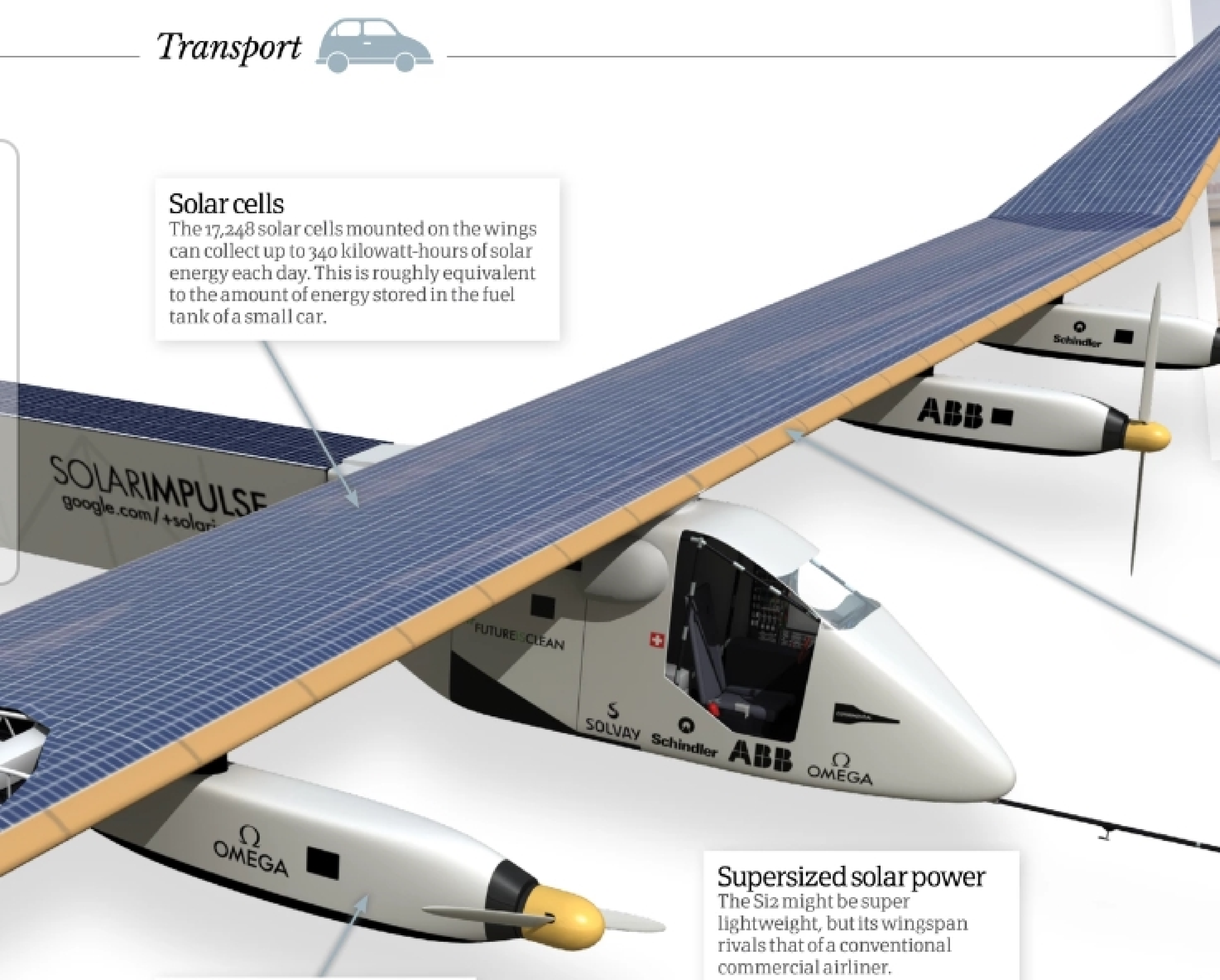
Batteries
633kg of lithium polymer batteries store the energy harvested from the solar cells to enable the plane to continue flying throughout the night. These account for over a quarter of the aircraft's weight.



July 2015
The longest leg of the journey between Japan and Hawaii causes thermal damage to the batteries, meaning the Si2 has to undergo repairs until the following year.

June 2015
The craft makes good time, traversing Asia quickly with few problems.

9 March 2015
Si2 begins its circumnavigation attempt, departing from Abu Dhabi in the United Arab Emirates.



Solar cells

The 17,248 solar cells mounted on the wings can collect up to 340 kilowatt-hours of solar energy each day. This is roughly equivalent to the amount of energy stored in the fuel tank of a small car.

Compromise

The Si2 team needed to use cells that were the ideal combination of lightweight, flexible and efficient. These solar cells can convert sunlight to electricity at an efficiency of 23 per cent.

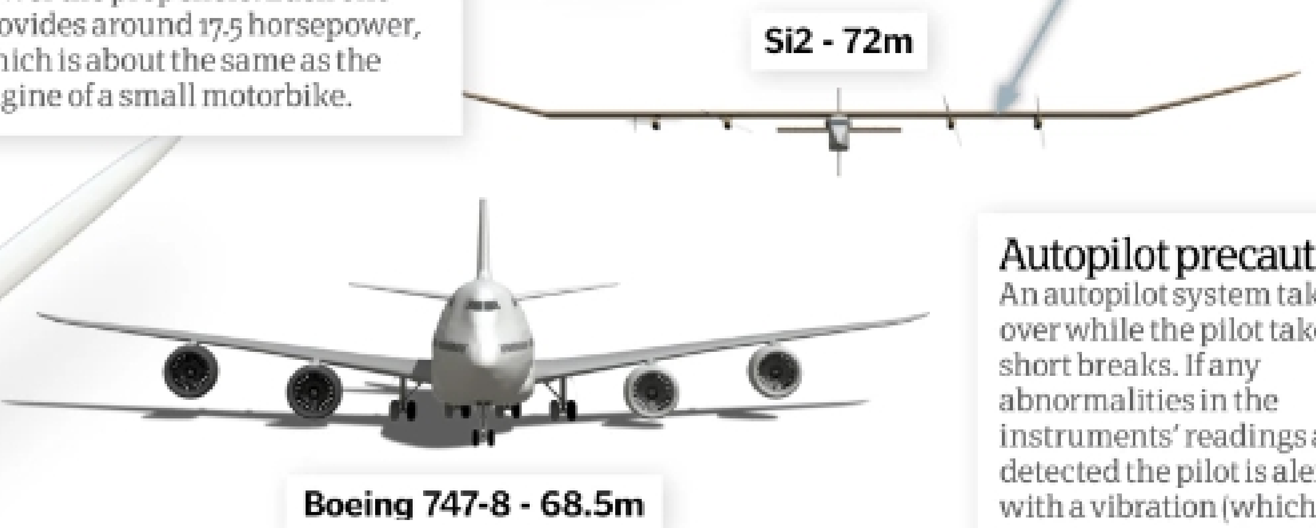
Motors

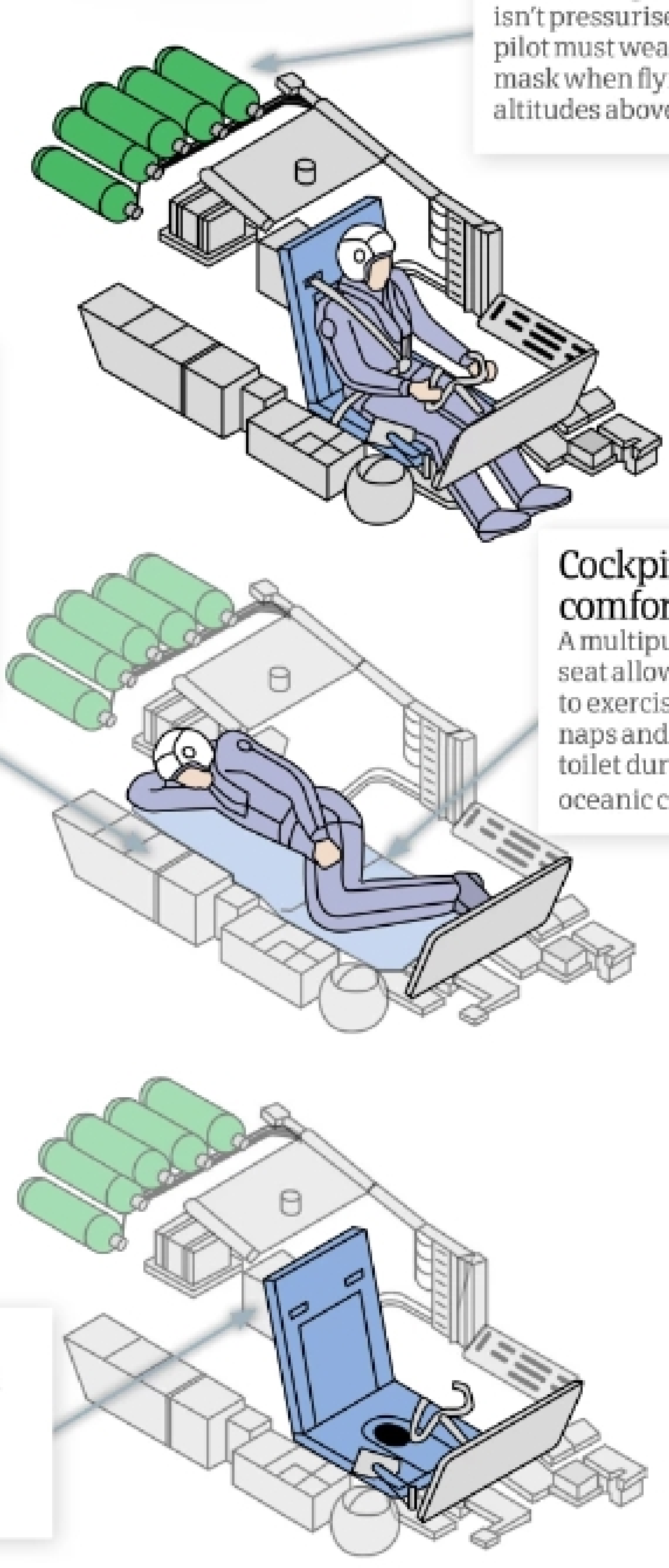
The plane's four electric motors power the propellers. Each one provides around 17.5 horsepower, which is about the same as the engine of a small motorbike.

More than just the pilots, Bertrand Piccard (left) and André Borschberg (right) are the chairman and CEO respectively of Solar Impulse, and advocates of clean energy solutions

Supersized solar power

The Si2 might be super lightweight, but its wingspan rivals that of a conventional commercial airliner.





Oxygen tanks

To save weight the cockpit isn't pressurised, so the pilot must wear an oxygen mask when flying at altitudes above 3,600m.

Autopilot precautions

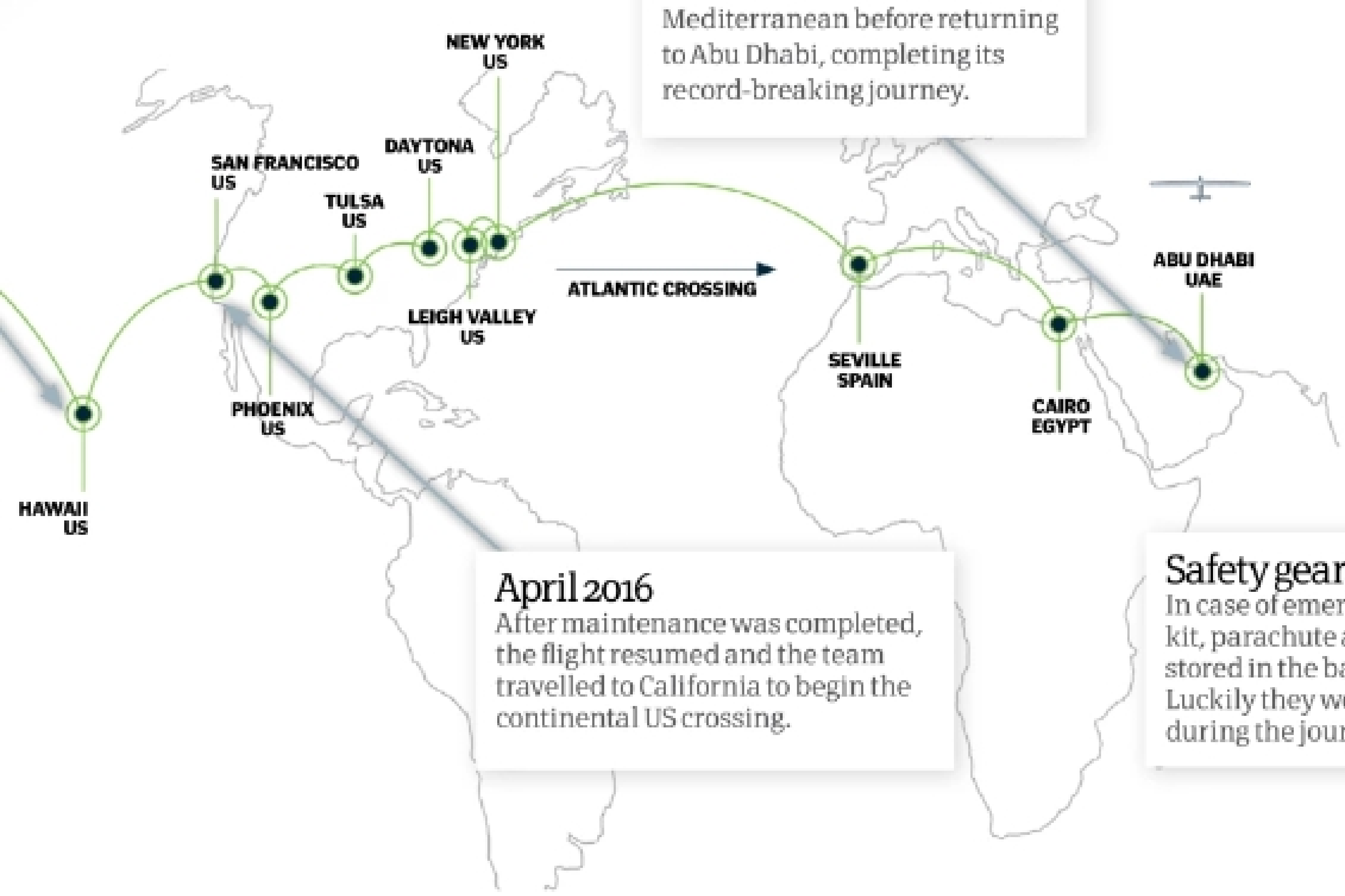
An autopilot system takes over while the pilot takes short breaks. If any abnormalities in the instruments' readings are detected the pilot is alerted with a vibration (which is sent via armbands on their flight suit) and an alarm.

Cockpit comfort

A multipurpose seat allows the pilot to exercise, take naps and go to the toilet during long oceanic crossings.

Safety gear

In case of emergency, a survival kit, parachute and life raft are stored in the back of the seat. Luckily they weren't needed during the journey.



July 2016

On the home straight, Si2 crossed the Atlantic and the Mediterranean before returning to Abu Dhabi, completing its record-breaking journey.

April 2016

After maintenance was completed, the flight resumed and the team travelled to California to begin the continental US crossing.

© Illustration by Adrian Mann; Solar Impulse

WILL ROCKETS REPLACE PLANES?

Come aboard and find out why rockets are set to replace commercial aircraft

Words by **James Horton**

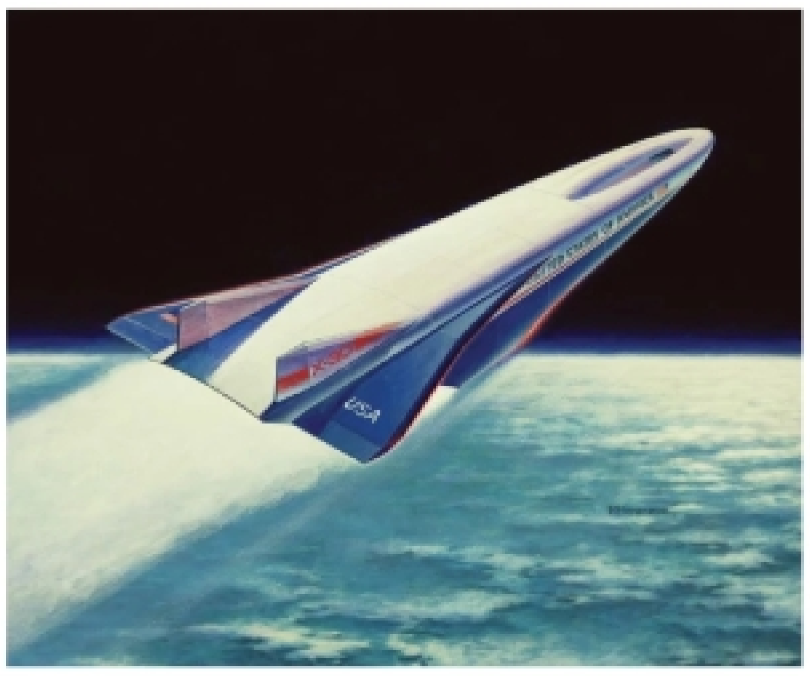
"Anywhere in the world, in less than an hour." Elon Musk and his company SpaceX may have already revolutionised the way we utilise rocketry, but now they seek to use their technology to take us to Mars, the Moon, and even from city to city. And, quite amazingly, the price of enjoying this last application could cost the same as an economy airline ticket.

Known as the 'Big Falcon Rocket', or more simply as the BFR, SpaceX's upcoming spacecraft is set to satisfy all of our space-faring needs in one neat package. It will build upon the staggering success of their previous two rocket designs: the Falcon 9, which at the time of writing has successfully completed nine launches in 2018, and the Falcon Heavy, which first took to the skies in February of this year. These rockets have demonstrated for the first time in our history that not only can you land the first stage of a rocket booster on the ground safely, but you can reuse it. It is from this milestone that the BFR's goal to not only take people off-world, but also shuttle them around it, becomes both viable and immensely promising for the future.

Standing at a mammoth 106 metres in total, the BFR will be composed of two major stages: a 58-metre-tall booster used to lift the vehicle into orbit, and a ship mounted atop the booster. This front portion will be equipped with 1,100 tons of additional fuel and boast a large, pressurised cabin for its city-to-city launches. This will give the BFR everything it will need to send its customers into sub-orbit and speeding around the globe. Here, passengers will be treated to not only arriving at their destination ludicrously quickly, but also to the majestic views of our planet that so far only a few lucky individuals have seen. Surely those sights alone will justify the cost of the ticket, with the fast arrival time becoming a rather big cherry on top.

It should be noted that SpaceX is not alone in its lofty ambitions. Not so far away another private company, Virgin Galactic, are creeping ever closer to their own sub-orbital flights. They plan for these to initially be sold for recreation and research, but also harbour long-term goals of trans-continental transport. Unlike the BFR, their two-component system involves a jet-powered carrier aircraft and an attached rocket-powered ship, which releases from the carrier craft and launches towards space once at altitude. Across the Atlantic, UK company Reaction Engines also dream of a vehicle that can soar from the runway to space as one whole unit. Their pioneering air-breathing SABRE engine aims to be an alternative to pure rocket power or jet engine/rocket hybrids like that of Virgin Galactic. Although this technology isn't currently as tangible as SpaceX's, it would almost certainly have incredible transport applications if it were to come to fruition.

In 1873, Jules Verne published a story about a man's attempt to race around the world in 80 days. It is a tale of great adventure, but one that pales in comparison to the journey that we have taken as a species in the years since its publication. We have ascended from the ground to the air, and from the air to the realm beyond. In fact, such is the staggering progress of our technological prowess over these years that by 2023, getting around the world in 80 minutes may not be quite quick enough.



Rocket travel would revolutionise global travel by dramatically cutting down journey times

Same goal, different approach

SpaceX's plan to utilise a sub-orbital vehicle for incredibly fast transport isn't a new one. Even decades earlier in 1986, when Ronald Reagan announced his plans to fund a vehicle that could get from Washington DC, US, to Tokyo, Japan, in two hours, it wasn't a novel idea. But the difference between SpaceX's ideas and those of the past has rested in their approach to the problem. Reagan's government and NASA wanted to construct the National Aero-Space Plane (NASP) as a single unit that could act as both aircraft and spacecraft with a unique engine design. They had shied away from rockets due to their one-use-only restriction. But the answer to finding a commercial space-faring vehicle, as SpaceX has shown, didn't lie in finding a new way to generate enough thrust to get into orbit, but in a way to make the rocket stages reusable.

Designers anticipated that the NASP concept would travel at up to 25 times the speed of sound

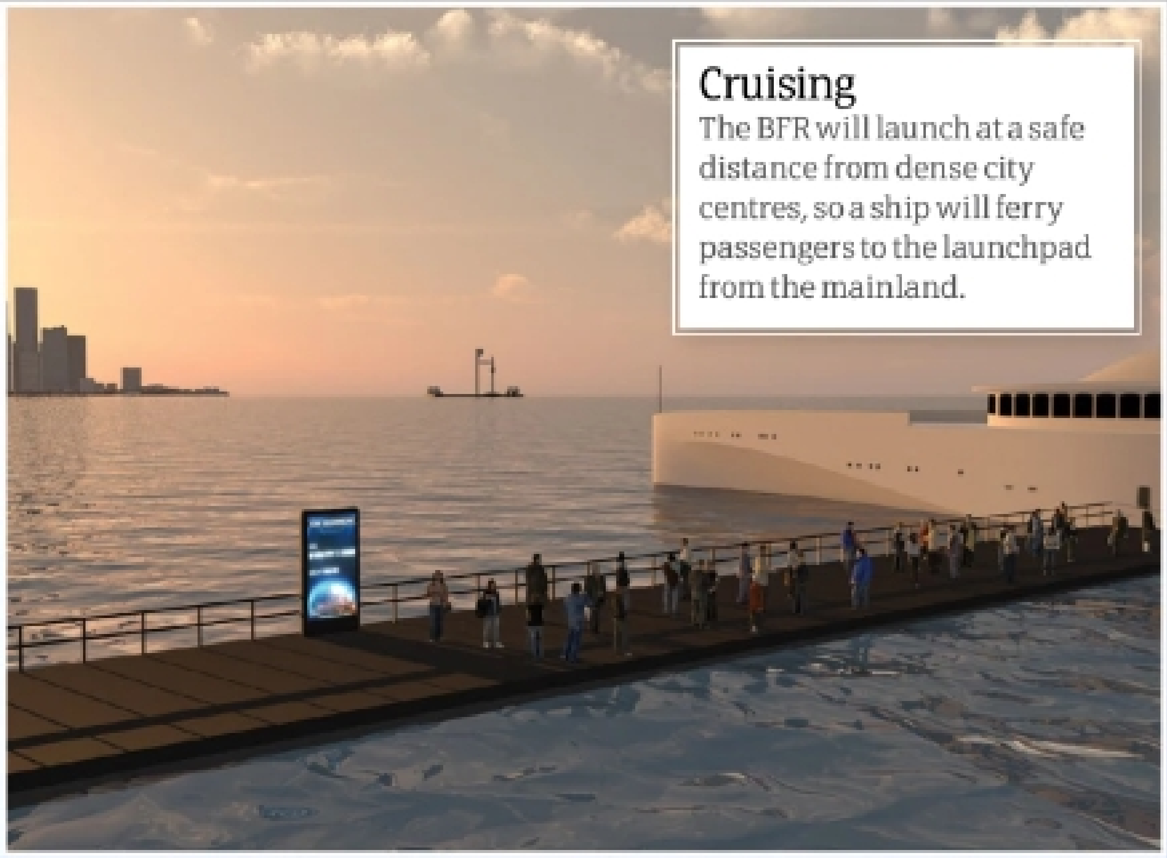
Virgin Galactic's spacecraft will first be lifted to altitude by a carrier jet

Virgin's SpaceShipTwo will use rocket power to ascend from the skies into sub-orbit

© Getty; NASA; Virgin Galactic

City-to-city on the BFR

Hop aboard the Big Falcon Rocket and travel to anywhere in the world in under 60 minutes

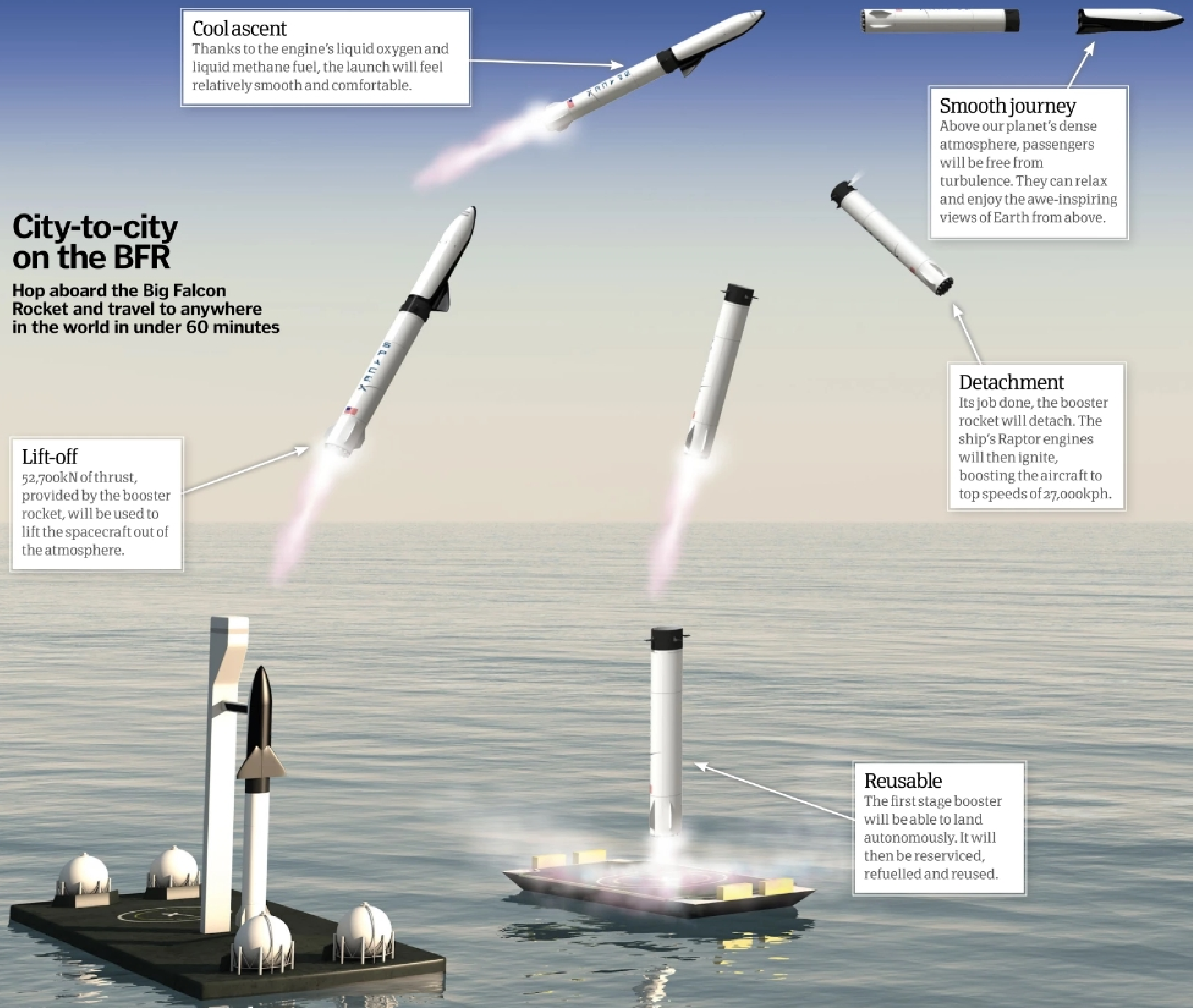


Cruising

The BFR will launch at a safe distance from dense city centres, so a ship will ferry passengers to the launchpad from the mainland.

All aboard

Passengers will ascend and enter the 106m-tall vehicle. Inside, the pressurised compartment will be larger than an A380's main deck.



Lift-off

52,700kN of thrust, provided by the booster rocket, will be used to lift the spacecraft out of the atmosphere.

Cool ascent

Thanks to the engine's liquid oxygen and liquid methane fuel, the launch will feel relatively smooth and comfortable.

Detachment

Its job done, the booster rocket will detach. The ship's Raptor engines will then ignite, boosting the aircraft to top speeds of 27,000kph.

Smooth journey

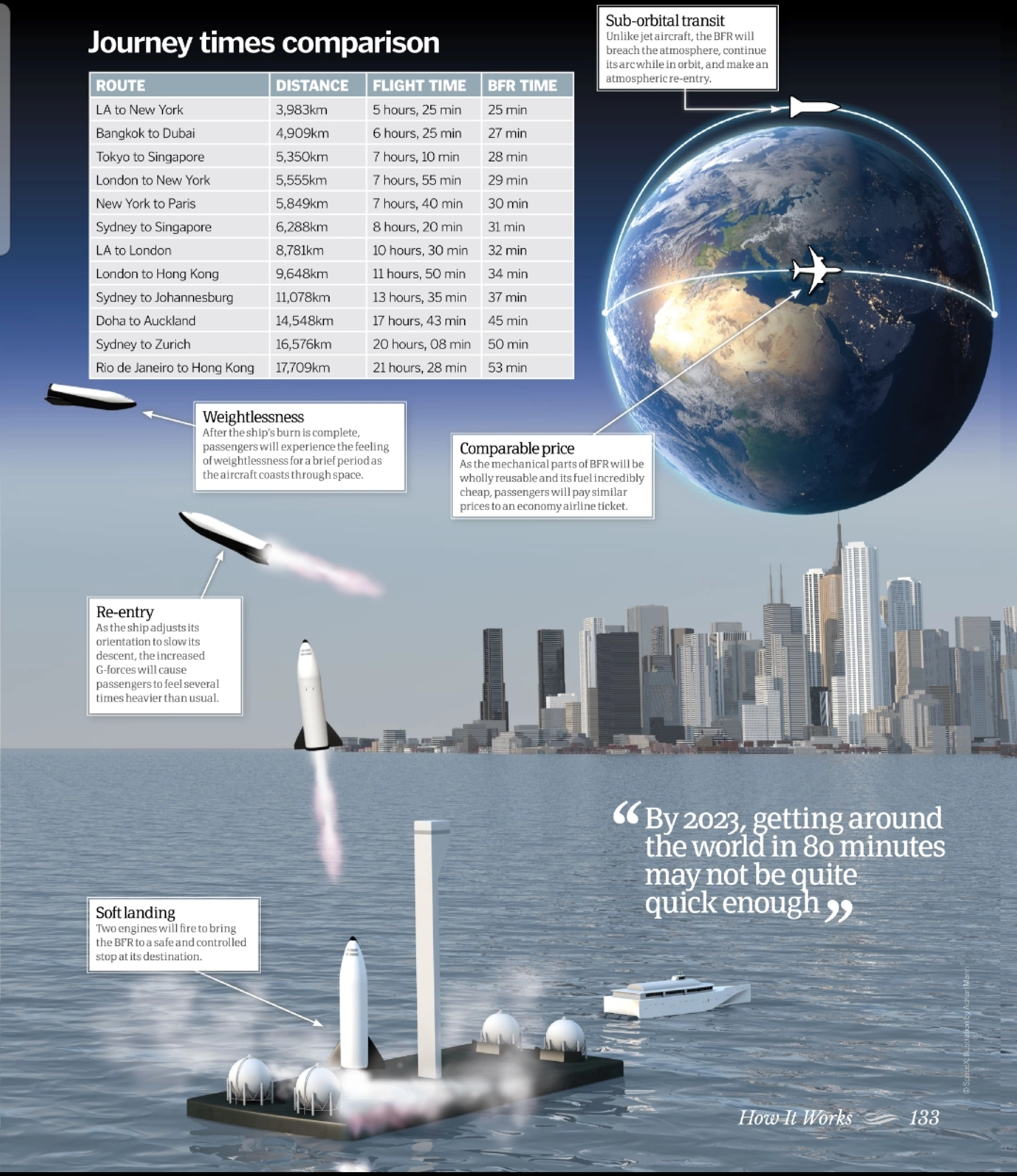
Above our planet's dense atmosphere, passengers will be free from turbulence. They can relax and enjoy the awe-inspiring views of Earth from above.

Reusable

The first stage booster will be able to land autonomously. It will then be reserviced, refuelled and reused.

Journey times comparison

ROUTE	DISTANCE	FLIGHT TIME	BFR TIME
LA to New York	3,983km	5 hours, 25 min	25 min
Bangkok to Dubai	4,909km	6 hours, 25 min	27 min
Tokyo to Singapore	5,350km	7 hours, 10 min	28 min
London to New York	5,555km	7 hours, 55 min	29 min
New York to Paris	5,849km	7 hours, 40 min	30 min
Sydney to Singapore	6,288km	8 hours, 20 min	31 min
LA to London	8,781km	10 hours, 30 min	32 min
London to Hong Kong	9,648km	11 hours, 50 min	34 min
Sydney to Johannesburg	11,078km	13 hours, 35 min	37 min
Doha to Auckland	14,548km	17 hours, 43 min	45 min
Sydney to Zurich	16,576km	20 hours, 08 min	50 min
Rio de Janeiro to Hong Kong	17,709km	21 hours, 28 min	53 min



Sub-orbital transit
Unlike jet aircraft, the BFR will breach the atmosphere, continue its arc while in orbit, and make an atmospheric re-entry.

Weightlessness
After the ship's burn is complete, passengers will experience the feeling of weightlessness for a brief period as the aircraft coasts through space.

Comparable price
As the mechanical parts of BFR will be wholly reusable and its fuel incredibly cheap, passengers will pay similar prices to an economy airline ticket.

Re-entry
As the ship adjusts its orientation to slow its descent, the increased G-forces will cause passengers to feel several times heavier than usual.

Soft landing
Two engines will fire to bring the BFR to a safe and controlled stop at its destination.

> "By 2023, getting around the world in 80 minutes may not be quite quick enough"

© SpaceX; Illustration by Adrian Mann

How do gliders stay airborne?

These engine-free vehicles have more in common with paper planes than you might expect…

The glide ratio for some commercial gliders can be as high as 60

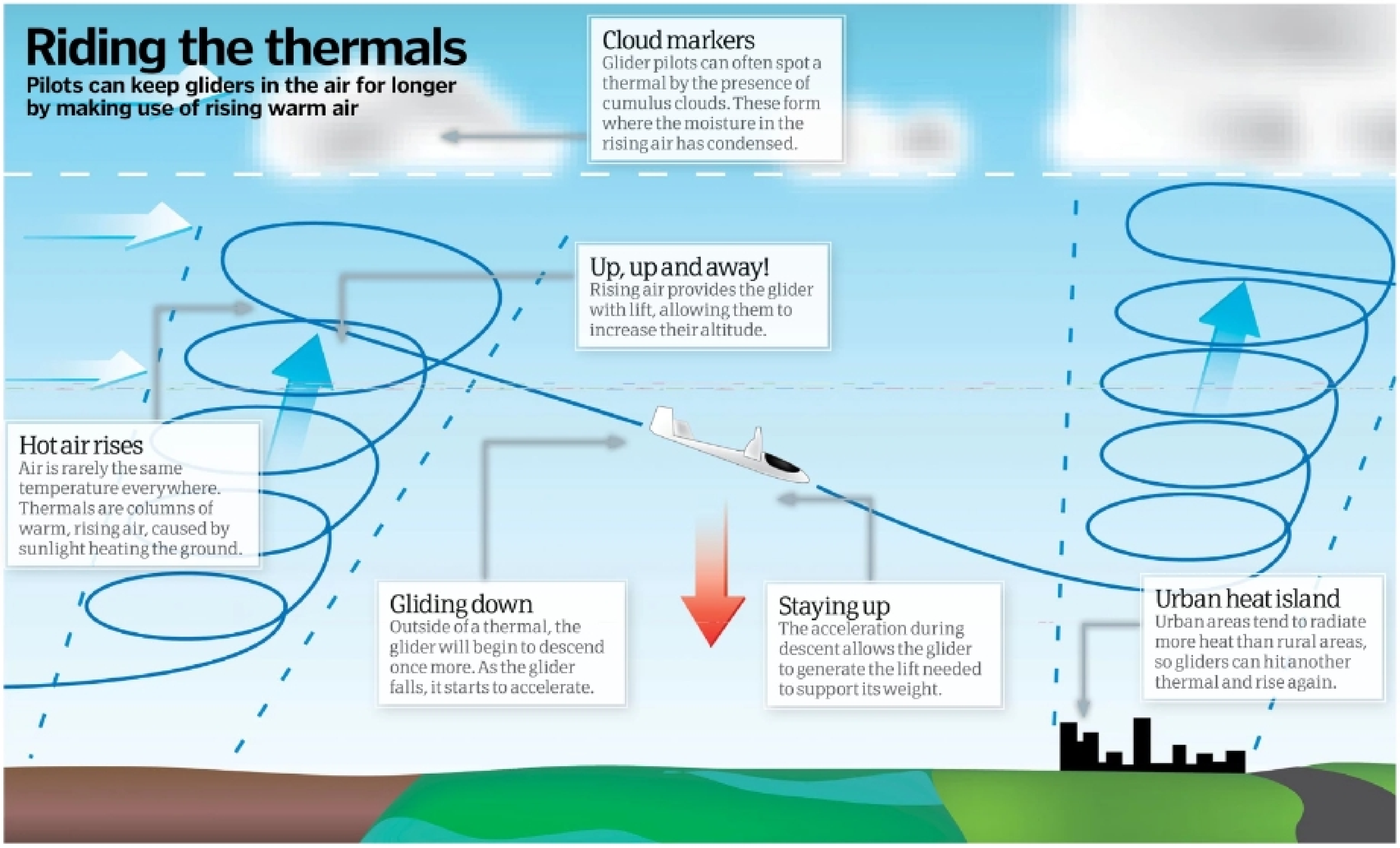
In its basic form, a glider is an aircraft with no engine, so they fly differently from powered aircraft due to the forces involved. When flying, a powered aircraft has four forces acting on it: lift, drag, weight (related to gravity) and thrust. Without an engine, gliders have no thrust, so they need to find other ways to generate speed. Key to this are a glider's wings – because they are so long, they generate huge amounts of lift, more than enough to help counteract the effect of gravity.

The glider needs some help to get into the air, though. There are two common ways to launch: either by towing it behind a powered plane as it takes off, before releasing it at altitude, or by rapidly winching along by a cable attached to a heavy-duty road vehicle. Once the glider gets up to speed, the wings come into their own, and the aircraft can take off. Alternatively, hang-glider pilots can run and jump off a hill or cliff to start their flight.

Really, the process of gliding is a very, very slow fall towards the ground. The speed of that descent is defined by its glide ratio, which tells you how far a glider can fly versus how much its altitude will drop. Hang-gliders have a glide ratio of around 15, which means that they can fly forward for 15 kilometres for every one kilometre of lost height. Commercial gliders, sometimes called sailplanes, descend much more slowly than hang-gliders – in fact, their glide ratios can be as high as 60.

Riding the thermals

Pilots can keep gliders in the air for longer by making use of rising warm air



Cloud markers
Glider pilots can often spot a thermal by the presence of cumulus clouds. These form where the moisture in the rising air has condensed.

Up, up and away!
Rising air provides the glider with lift, allowing them to increase their altitude.

Hot air rises
Air is rarely the same temperature everywhere. Thermals are columns of warm, rising air, caused by sunlight heating the ground.

Gliding down
Outside of a thermal, the glider will begin to descend once more. As the glider falls, it starts to accelerate.

Staying up
The acceleration during descent allows the glider to generate the lift needed to support its weight.

Urban heat island
Urban areas tend to radiate more heat than rural areas, so gliders can hit another thermal and rise again.

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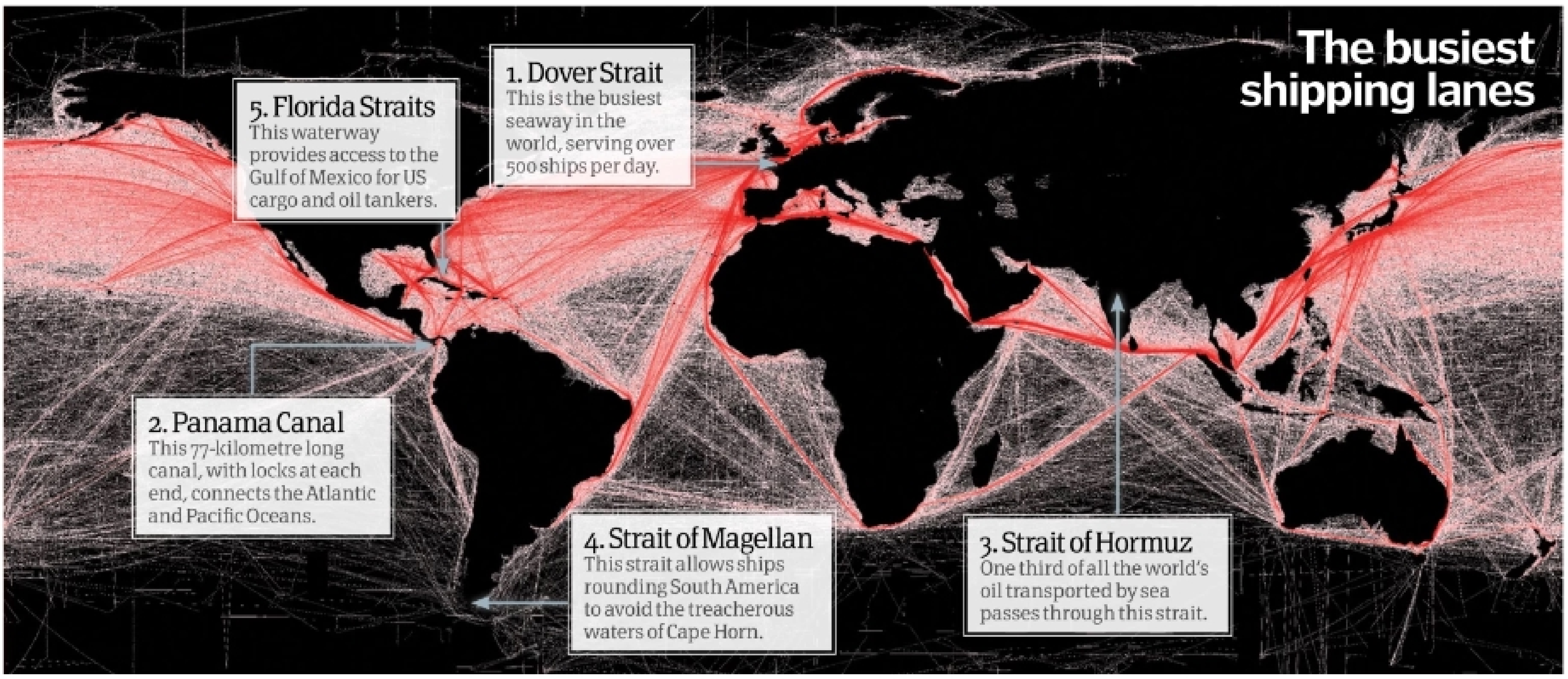


The busiest shipping lanes

1. Dover Strait
This is the busiest seaway in the world, serving over 500 ships per day.

2. Panama Canal
This 77-kilometre long canal, with locks at each end, connects the Atlantic and Pacific Oceans.

3. Strait of Hormuz
One third of all the world's oil transported by sea passes through this strait.

4. Strait of Magellan
This strait allows ships rounding South America to avoid the treacherous waters of Cape Horn.

5. Florida Straits
This waterway provides access to the Gulf of Mexico for US cargo and oil tankers.

What are shipping lanes?

90 per cent of the world's goods are transported by sea, so how is the traffic managed?

It is estimated that in 2007, retail giant Walmart imported an average of one shipping container to the US from China every minute. That year alone, over 4,500 ships carried 18 million shipping containers between the world's ports. These ships are all concerned with reaching their destination in the shortest time and with the lowest fuel costs, so certain routes can get extremely crowded.

In the English Channel there is a contraflow system, which means that ships travelling south use the English side of the channel and northbound traffic uses the French side. This is enforced by the Dover Strait TSS, a radar-controlled traffic separation scheme operated by the International Maritime Organisation.

Sea lanes began with the trade routes used by sailing ships that exploited the prevailing winds across the oceans. Although modern cargo ships use engines, today's sea lanes mostly follow the same routes because rough seas can still cause expensive delays. Close to the shore, shipping lanes are routed to ensure there is enough depth of water for the huge cargo vessels. Smaller, more manoeuvrable boats normally keep out of shipping lanes to reduce the risk of collision with these commercial leviathans.

How do cat's eyes work?

Discover exactly how these reflective patches mark out a driver's route in the dark

Invented by Yorkshireman Percy Shaw, 'cat's eyes' are reflective markers found on roads across the world. Their name was inspired by the eerie glow given off by the eyes of cats and other nocturnal hunters when a light is shone on them. In cats, this reflectivity is due to a layer of silvery-green tissue at the back of their eyes – as well as reflecting light, it also helps cats to see in the dark.

To reproduce this effect, cat's eye road markers use two tiny studs, made from lozenge-shaped glass beads that have one end coated with an aluminium mirror. As the light from a vehicle's headlamps enters the front of the glass beads, it bends slightly, reflects off the mirrors, and bounces back into the driver's eyes.

Cat's eyes are ultra-durable too. The mirrored beads are set into a tough rubber dome, which is surrounded by a ring of cast iron. If a vehicle drives directly over it, the rubber dome briefly sinks into the road, but bounces back unscathed. Cat's eyes can be produced in any colour – white, yellow and green are the most common.

Cat's eyes are the simplest, power-free way to mark roads in the dark

© B.S Halpern

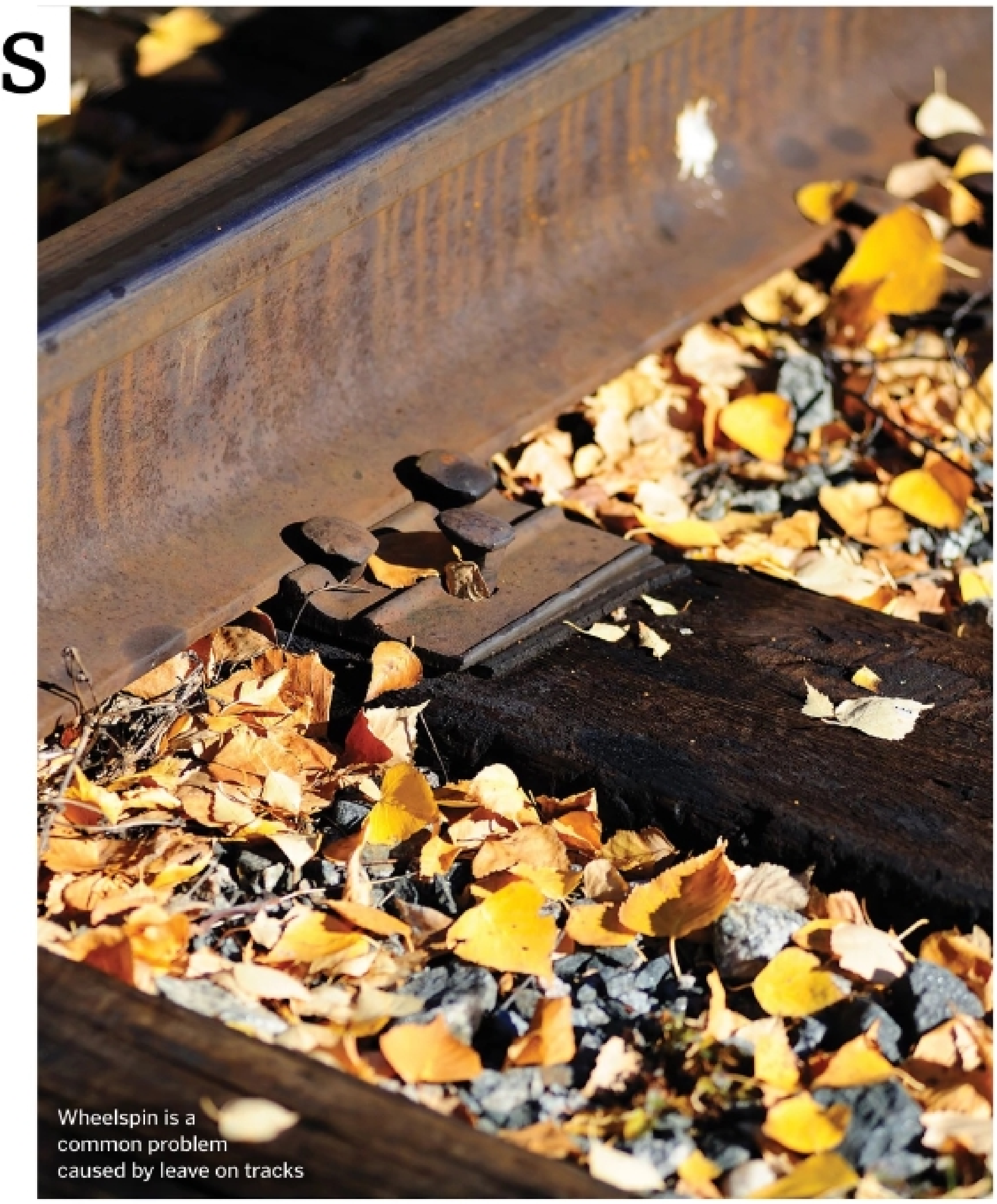
Why do leaves on the line affect trains?

There is a legitimate reason behind all of those delays

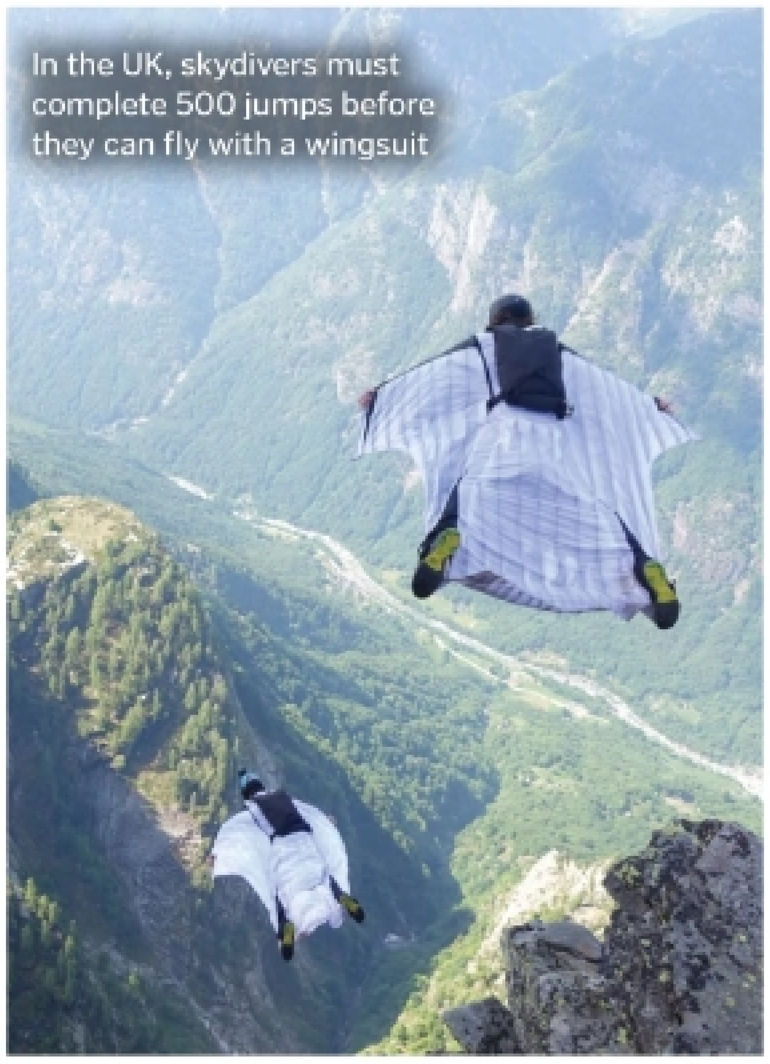
In the UK, a mature tree has between 10 and 50,000 leaves, poised to fall on railway tracks every autumn and cause delays and frustration for commuters. That's because when trains flatten the foliage, they leave behind a slimy muck, which is similar to Teflon – the non-stick coating on saucepans. To avoid wheelspin, train drivers have to brake early and accelerate gently, and this safety precaution leads to delays.

To help combat this problem, modern trains are fitted with wheel slip protection, which operates just like automatic braking systems on road vehicles. The system monitors the rotation of each axle, and if one happens to be spinning faster than the other, the brake is then released until the speed equalises, then the brake is reapplied to the wheels.

Trains can also spray ultra-fine sand ahead of the wheels to help aid traction, or a fleet of Railhead Treatment Trains can do the same thing on a larger scale. They spray high-powered jets of water along the tracks to clear them, then apply an adhesive paste – a mixture of sand and aluminium called 'sandite' – on the lines to improve grip. These trains run during off-peak hours to get the tracks cleared for the busiest commuting times.



Wheelspin is a common problem caused by leave on tracks



In the UK, skydivers must complete 500 jumps before they can fly with a wingsuit

How do wingsuits work?

Fly like a bird with a soaring suit and a little bit of science

After leaping out of a plane, skydivers fall to the ground at almost 200 kilometres per hour, making their entire descent a bit of a blur. However, by putting on some clever parachute-like clothing, they can slow down their dive and regain some control, enabling them to soar horizontally as well as vertically and perform some impressive aerial acrobatics.

By wearing a wingsuit, a skydiver transforms themselves into a giant wing, with their body acting as the rigid framework, and the fabric between the legs and beneath the arms creating a large horizontal surface, or airfoil. After leaving the plane, the jumper's weight pulls them down, but as they spread their arms and legs, air resistance created by the airfoil generates lift, slowing down their rate of descent. To glide horizontally, the skydiver must then bring their arms in a little and keep their head low in order to reduce the amount of drag, the force that opposes forward momentum.

While the suit is able to slow their descent to less than 100 kilometres per hour, this isn't slow enough for a safe landing, and so a parachute must be deployed to reduce speed before they reach the ground.

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How does the Sailrocket 2 work?

Find out how this boat hits such high speeds on the high seas

The design of the Sailrocket 2 perfectly balances forces for speed

When it comes to going super fast on water, powerboats are usually the go-to craft. However, there's one sailboat out there that is capable of achieving breakneck speeds of 65 knots (120 kilometres per hour) using wind power alone. It's called Sailrocket 2, and it's the brainchild of Paul Larsen, based on designs originally by an American rocket engineer in 1917.

The Sailrocket 2 is an aerodynamic mixture of plane and boat. Its ingenious design relies on a mixture of forces to keep it stable and to transfer the energy from the wind (that would cause a normal boat to capsize) into extra speed.

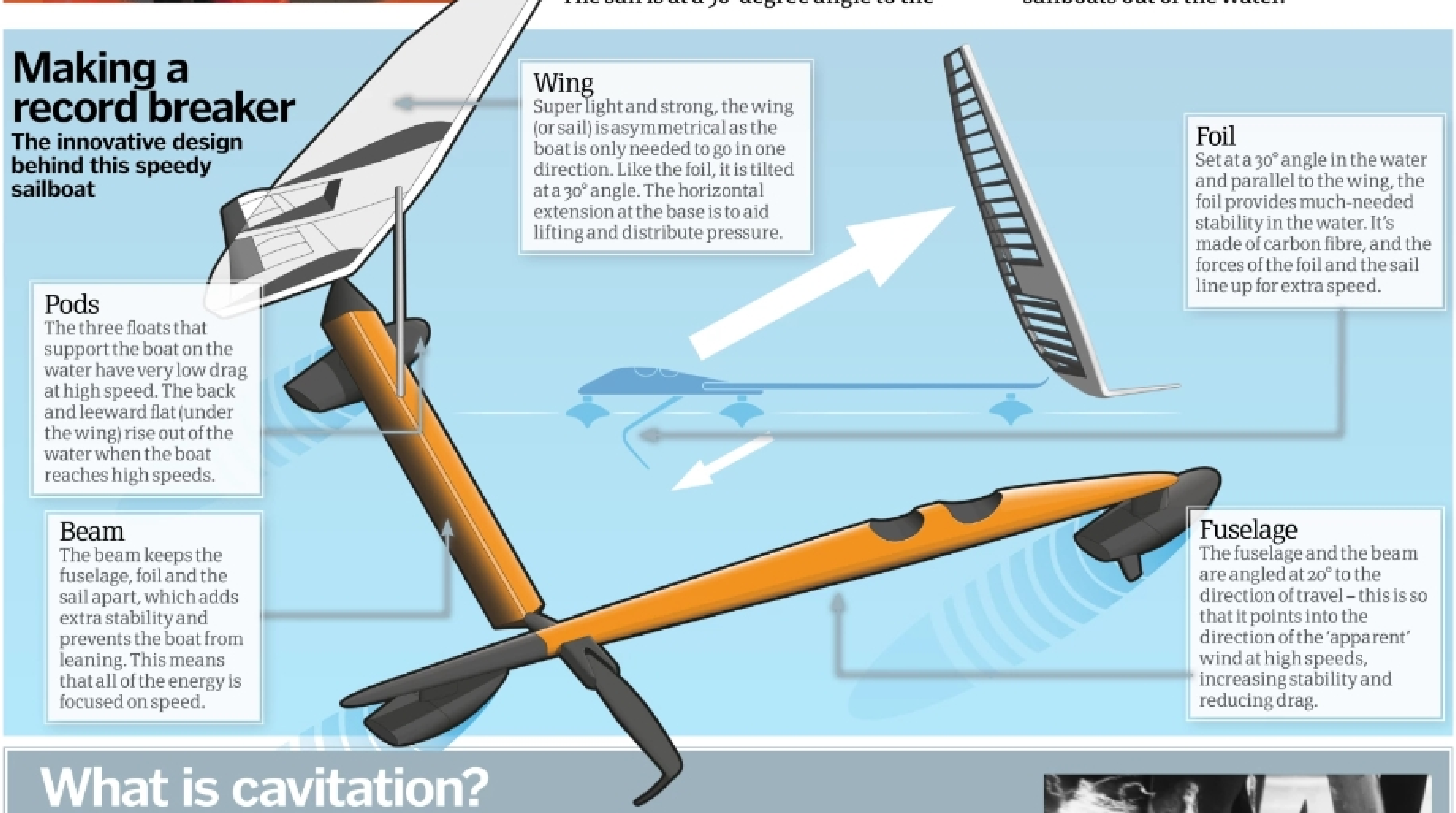
The cockpit (fuselage) sits parallel to the sail, attached by a horizontal mast. The sail is at a 30-degree angle to the water, and protruding from the cockpit is a bent carbon-fibre keel, or foil. The whole boat sits on the water atop three pods.

The foil is the real genius in this design; it's tough but thin, and helps to create minimum drag while stabilising the entire boat. It also counteracts cavitation (bubbles that cause drag) using a wedge-shape design that reduces the friction in the water caused by the phenomenon.

When the boat hits 50 knots (92 kilometres per hour), buoyancy is replaced by hydrodynamic lift. Two of the boat's pods lift out of the water, and it glides on pockets of air trapped between the pods and the water. The foil keeps it stable, allowing the Sailrocket 2 to reach record speeds, and blowing all other sailboats out of the water.

Making a record breaker

The innovative design behind this speedy sailboat



Wing
Super light and strong, the wing (or sail) is asymmetrical as the boat is only needed to go in one direction. Like the foil, it is tilted at a 30° angle. The horizontal extension at the base is to aid lifting and distribute pressure.

Pods
The three floats that support the boat on the water have very low drag at high speed. The back and leeward flat (under the wing) rise out of the water when the boat reaches high speeds.

Beam
The beam keeps the fuselage, foil and the sail apart, which adds extra stability and prevents the boat from leaning. This means that all of the energy is focused on speed.

Foil
Set at a 30° angle in the water and parallel to the wing, the foil provides much-needed stability in the water. It's made of carbon fibre, and the forces of the foil and the sail line up for extra speed.

Fuselage
The fuselage and the beam are angled at 20° to the direction of travel – this is so that it points into the direction of the 'apparent' wind at high speeds, increasing stability and reducing drag.

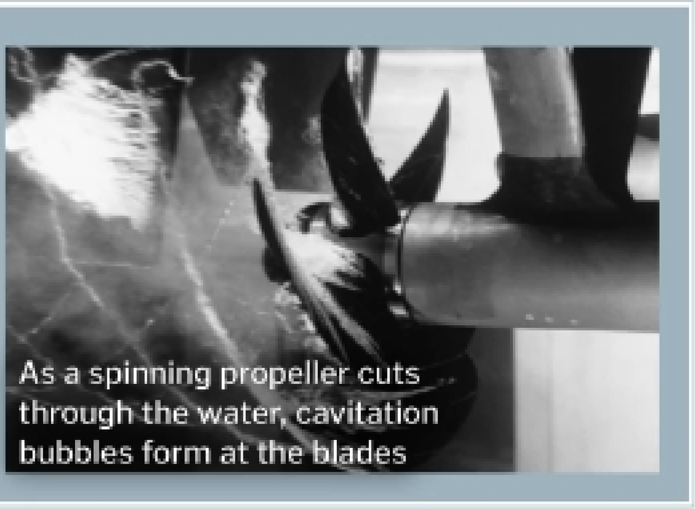
What is cavitation?

Cavitation is essentially the formation of bubbles (air pockets) in a liquid when it is under extremely high pressure. This happens when a foil cuts through water at speeds higher than the so-called '50-knot barrier' (the equivalent of 93 kilometres per hour).

The phenomenon is not fully understood, but it causes the seawater to vaporise and form intense bubbles – a little like boiling. This causes drag and prevents the boat from accelerating.

Breaking the 50-knot barrier can be difficult because the foil has to be small and light enough to enable the boat to go fast, but a smaller foil ultimately means a greater pressure change and more cavitation.

To combat this, instead of a smooth, wing-like design, Sailrocket 2's foil uses a wedge-shape to cut through the water and leave a smooth pocket of air in its wake, instead of a mass of chaotic bubbles.


As a spinning propeller cuts through the water, cavitation bubbles form at the blades

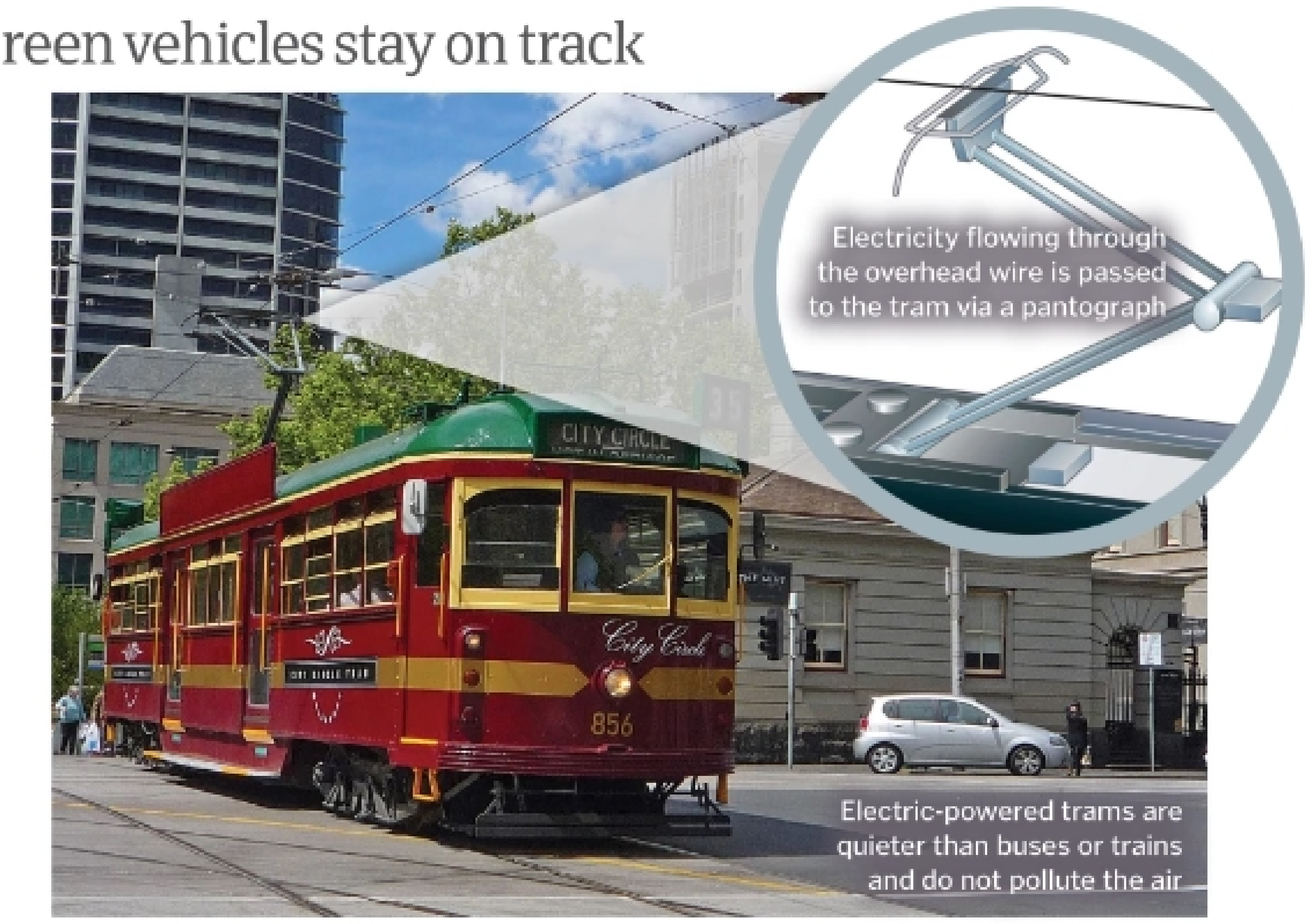
© Getty, Illustration by The Art Agency

How do trams work?

Hop aboard and discover how these green vehicles stay on track

The first trams were powered by horse and then steam, but the systems we have today are driven by electricity. Each tramcar has a long pole on its roof called a pantograph, which uses a spring-loaded mechanism to maintain contact with an overhead wire, called a catenary, running above the track. An electric current flowing through the wire is passed down the pantograph and to the tram's motors, which drive the wheels to keep it moving. To control the speed of the vehicle, the driver simply adjusts the amount of electricity that reaches the motors, increasing it to go faster, and decreasing it to go slower.

After flowing through the motors, the electricity is passed through the wheels to the rails of the track, where it flows back to the main power supply to complete the electric circuit. If any part of the circuit breaks, such as if the pantograph loses contact with the catenary wire, or the wheels come off of the track, the flow of electricity will stop and so will the tram.



Electricity flowing through the overhead wire is passed to the tram via a pantograph

Electric-powered trams are quieter than buses or trains and do not pollute the air

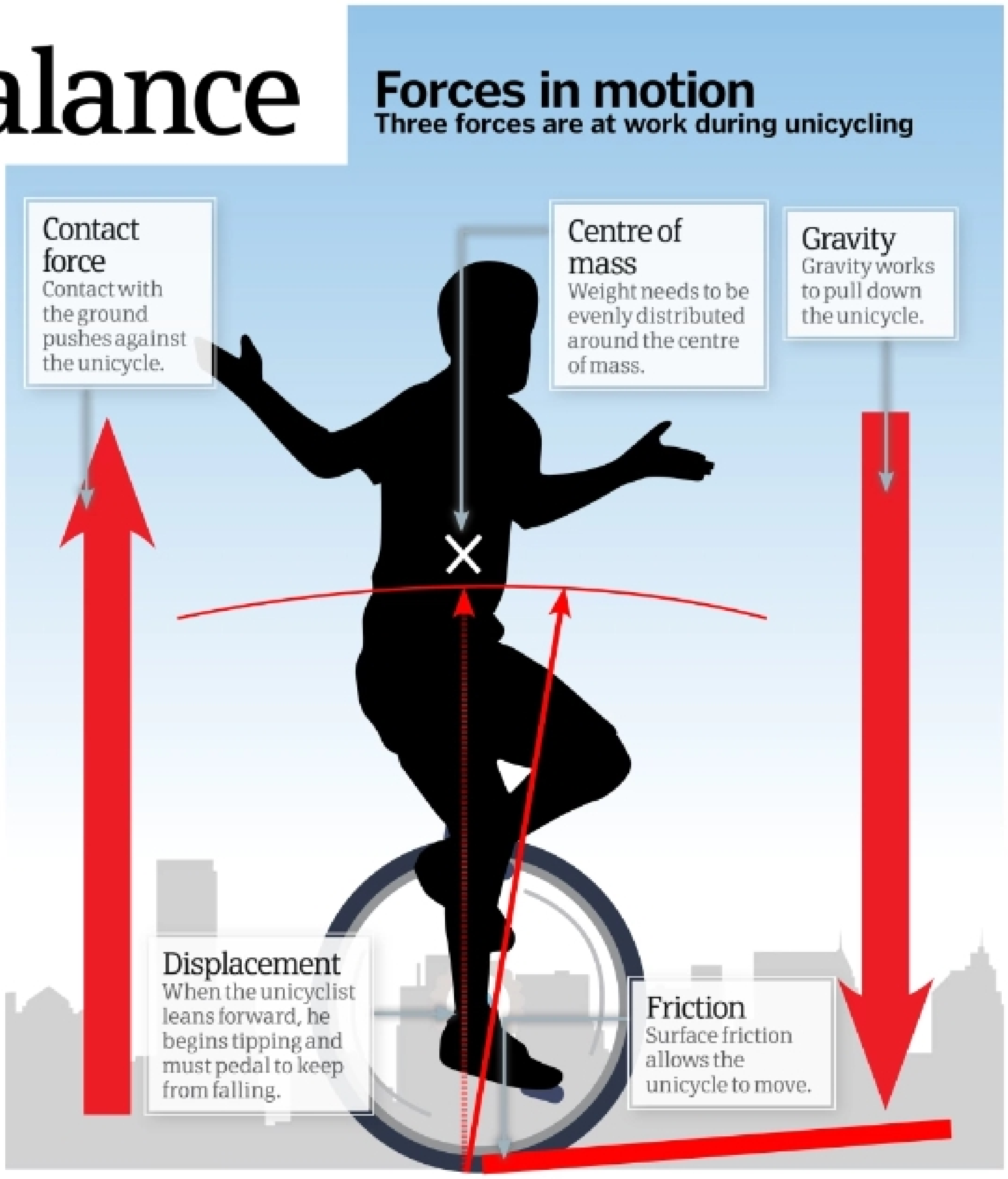
How do you balance on a unicycle?

Get a handle on the forces that keep you upright on one wheel

To balance on a unicycle, you have to keep pedalling. It's Newton's first law: an object in motion tends to stay in motion. Maintaining balance, however, is the hard part.

Three forces are at work here: gravity, contact and friction. Gravity pulls the unicycle down and contact force with the ground pushes back. The surface that the unicycle is moving along exerts friction, which is what allows the unicycle to balance, speed up and slow down. The rider has to keep perfect posture, in alignment with the frame of the unicycle. As soon as he starts to tip, he will fall as he is in unstable equilibrium. However, he must tilt his body to move.

In order to go forward, the unicyclist leans forward. This means changing the point of contact to maintain the centre of gravity, which means continuous pedalling. He also has to countersteer to turn. This means moving in the opposite direction to where he wants to go. To make a left turn, for example, he first steers slightly to the right so that he can lean to the left. It's a juggle of forces worthy of a circus.



Forces in motion

Three forces are at work during unicycling

Contact force
Contact with the ground pushes against the unicycle.

Centre of mass
Weight needs to be evenly distributed around the centre of mass.

Gravity
Gravity works to pull down the unicycle.

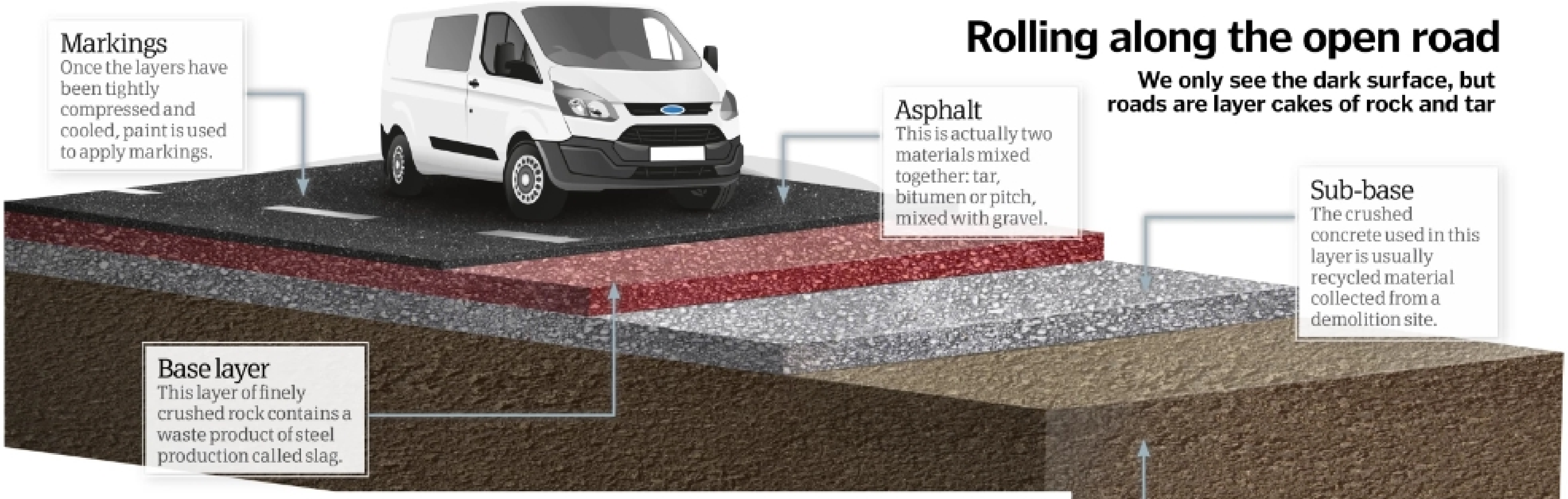
Displacement
When the unicyclist leans forward, he begins tipping and must pedal to keep from falling.

Friction
Surface friction allows the unicycle to move.

© Thinkstock

What makes up a road?

The construction process is more complex than you might think



Rolling along the open road

We only see the dark surface, but roads are layer cakes of rock and tar

Markings
Once the layers have been tightly compressed and cooled, paint is used to apply markings.

Asphalt
This is actually two materials mixed together: tar, bitumen or pitch, mixed with gravel.

Sub-base
The crushed concrete used in this layer is usually recycled material collected from a demolition site.

Base layer
This layer of finely crushed rock contains a waste product of steel production called slag.

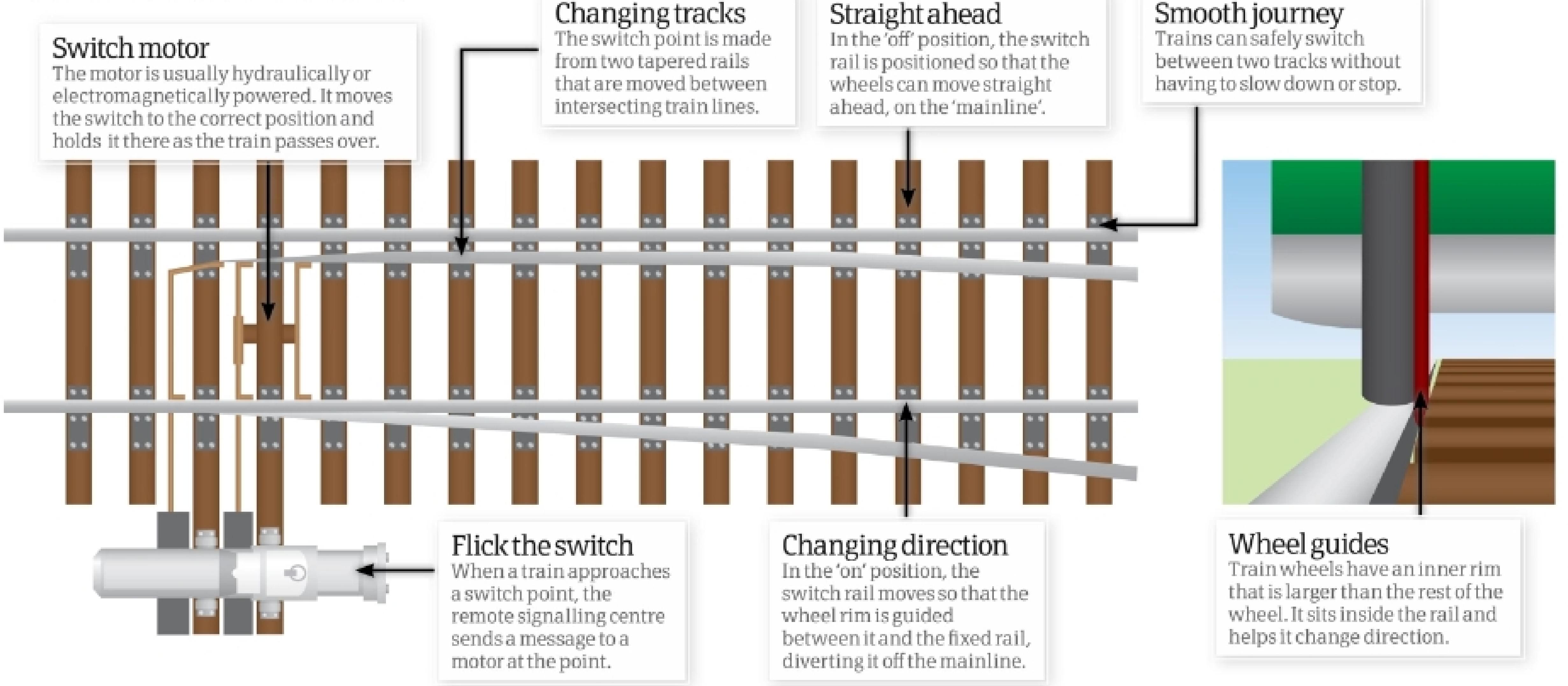
Sub-grade
The exposed soil is compacted by repeatedly driving over it with a roller.

It is believed that the first roads paved with bricks were constructed in the Indus Valley more than 5,000 years ago. Today, there are enough roads on Earth to circle the planet over 600 times, but bricks are no longer the material of choice when creating new roads. In fact, the roads of today are built using layers of many different materials.

Vehicles are heavy – a typical family car weighs well over a ton – which means that roads have to be tough enough to withstand the stresses involved. That's why the load is spread over four layers. At the bottom is the sub-grade – this is the local soil that is compressed with a roller. Next, you have the sub-base, typically made from crushed concrete. The base comes next – another layer of finely crushed rock mixed with asphalt and slag, which is a waste product from steel production. Then comes the smelly stuff – the binder and surface materials, collectively called tarmacadam. The 'tar' is the hot, sticky black substance, and 'macadam' is the gravel that is densely packed into the tar using a roller. Once it has cooled down, the road is complete.

How do trains change tracks?

The simple switches that let trains reach different destinations



Switch motor
The motor is usually hydraulically or electromagnetically powered. It moves the switch to the correct position and holds it there as the train passes over.

Changing tracks
The switch point is made from two tapered rails that are moved between intersecting train lines.

Straight ahead
In the 'off' position, the switch rail is positioned so that the wheels can move straight ahead, on the 'mainline'.

Smooth journey
Trains can safely switch between two tracks without having to slow down or stop.

Flick the switch
When a train approaches a switch point, the remote signalling centre sends a message to a motor at the point.

Changing direction
In the 'on' position, the switch rail moves so that the wheel rim is guided between it and the fixed rail, diverting it off the mainline.

Wheel guides
Train wheels have an inner rim that is larger than the rest of the wheel. It sits inside the rail and helps it change direction.

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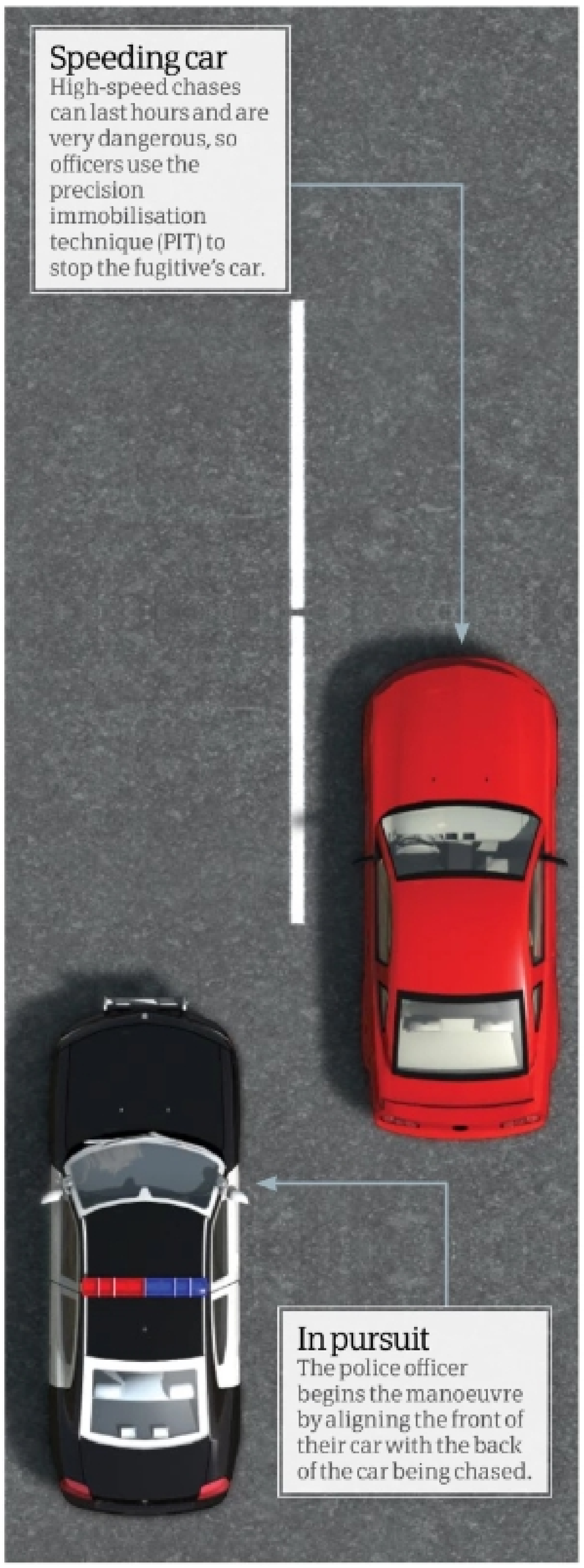
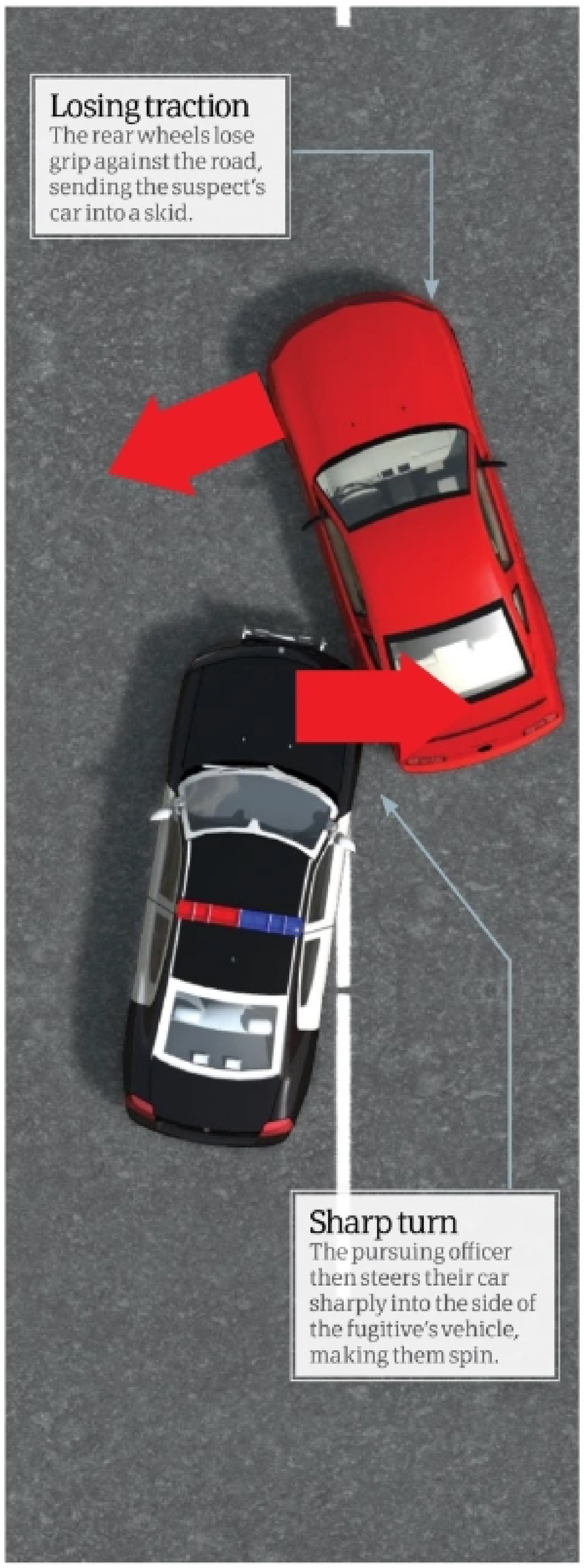
How do you stop a speeding car?



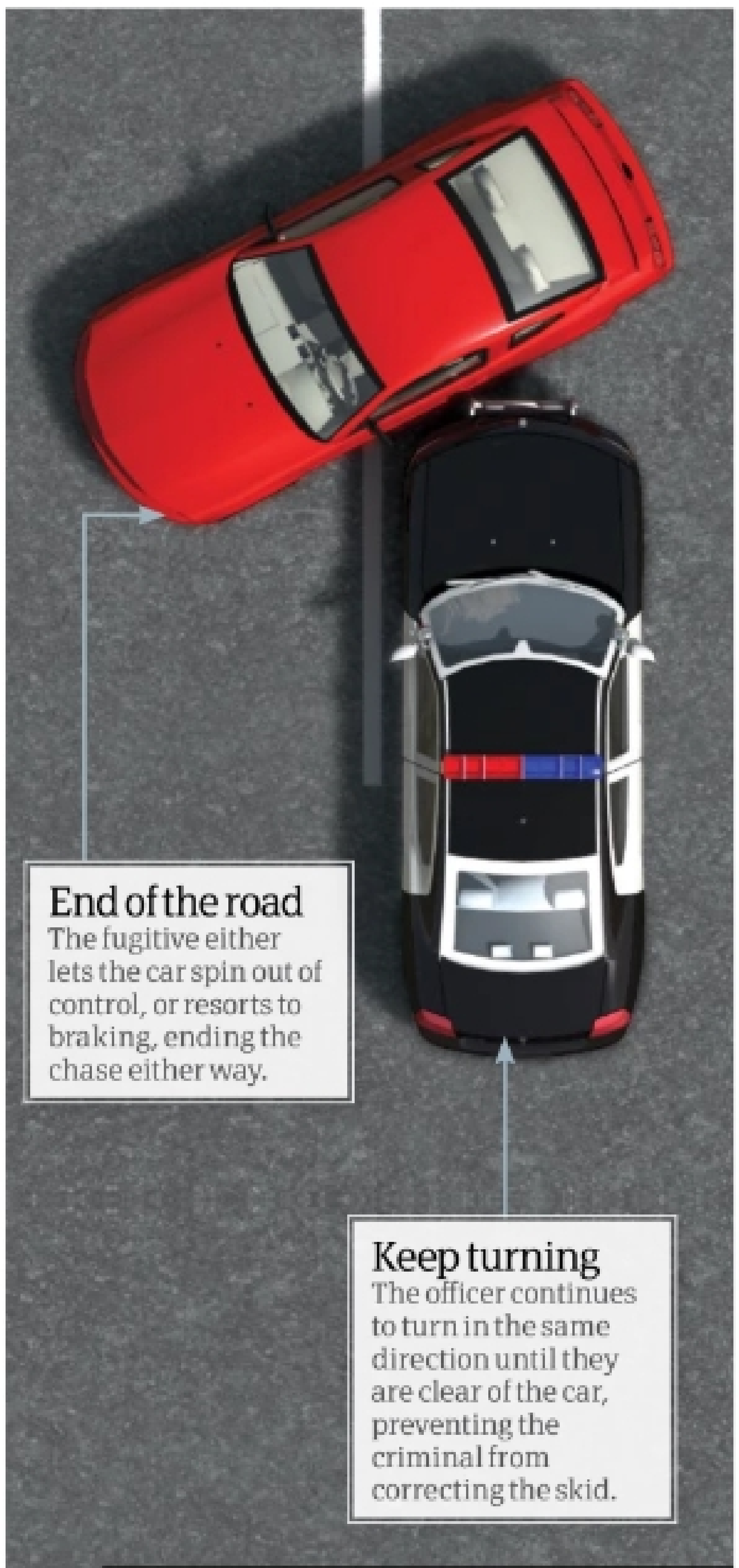
Speeding car
High-speed chases can last hours and are very dangerous, so officers use the precision immobilisation technique (PIT) to stop the fugitive's car.

In pursuit
The police officer begins the manoeuvre by aligning the front of their car with the back of the car being chased.



Losing traction
The rear wheels lose grip against the road, sending the suspect's car into a skid.

Sharp turn
The pursuing officer then steers their car sharply into the side of the fugitive's vehicle, making them spin.



End of the road
The fugitive either lets the car spin out of control, or resorts to braking, ending the chase either way.

Keep turning
The officer continues to turn in the same direction until they are clear of the car, preventing the criminal from correcting the skid.

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What is the best way to beat jet lag?

Controlling your light exposure and melatonin levels, ideally before you travel, is the most effective way of overcoming jet lag. These cues influence your circadian rhythm, an internal clock that governs sleep, hunger and other cycles – and causes you to feel jet-lagged when you switch time zones.

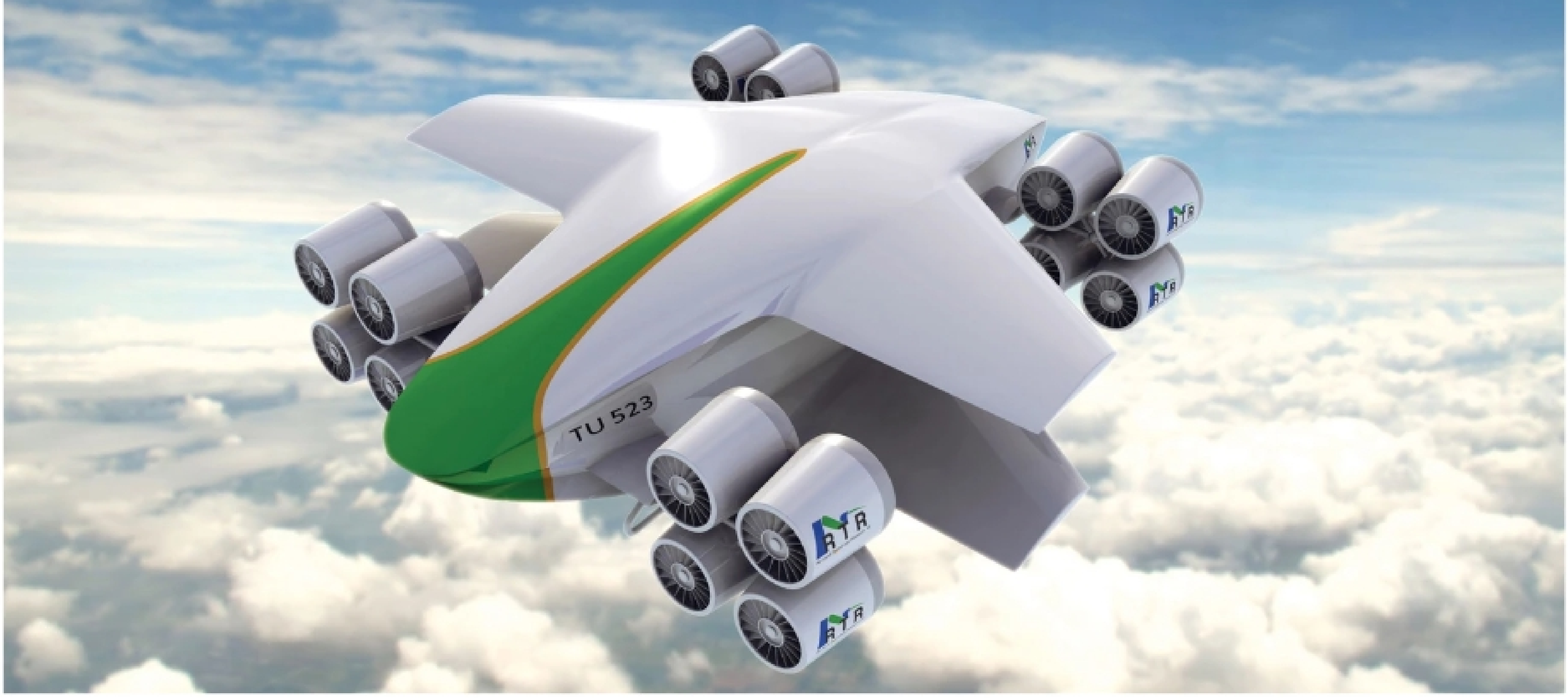
A few days before travelling, use a bright light to mimic the time of day at your destination. This will help you adapt to the change in time zones more easily. When it's early evening there, take melatonin, a hormone released naturally by your body to induce drowsiness and prompt you to sleep.

What is the future of VTOL aircraft?

The huge cargo containers that travel the world on enormous ships are currently passed onto large trucks when they reach port, and driven to their final destination by road. However, British company Reinhardt Technology Research (RTR) believes it would ultimately be quicker, cheaper, and more environmentally friendly to fly them instead.

The company has recently designed the TU 523, a vertical take-off and landing (VTOL) aircraft that is capable of transporting heavy shipping containers without the need for expensive new infrastructure. The craft uses a hybrid electric generator to supply power to a series of electric turbines on demand, which can tilt horizontally and enable vertical take-off and landing.

Once in the air, the turbines tilt back again, while the wings generate lift just like on an airplane. RTR has already built a 1:4 scaled model of the TU 523. It will then develop a full-scale version over the next three years, which can be mass-produced at a capacity of 30 units per month and cost no more than £400,000 ($580,000) each.

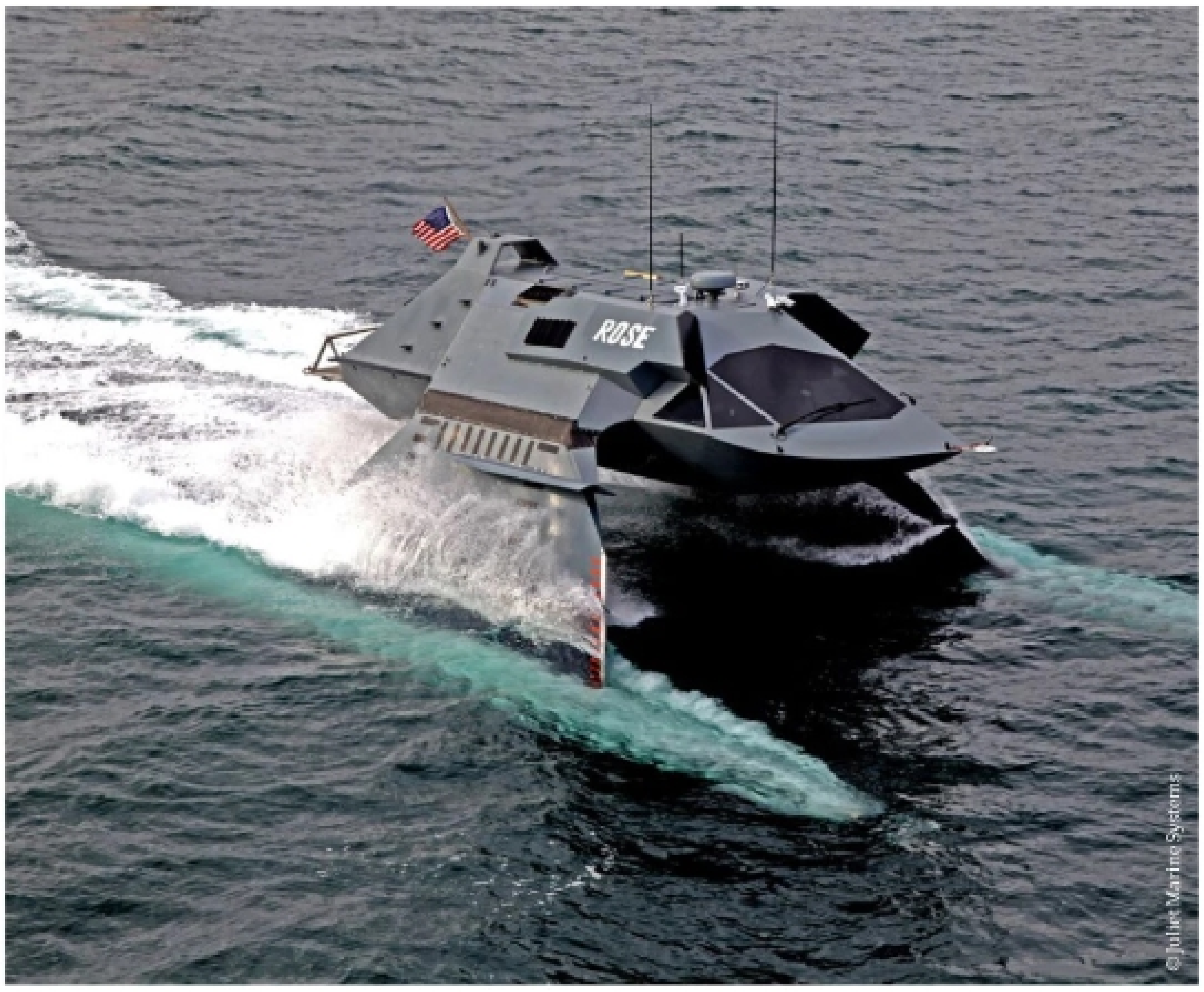


What are GHOST ships?

Minimising drag is an important consideration when designing ships, as friction between the vessel and water reduces efficiency. Juliet Marine Systems (JMS) Inc has tackled this problem by incorporating innovative tech into its demonstration ship called GHOST.

This twin-hull ship has two wing-like struts, the end of each strut features a submerged tubular hull containing the propulsion system. Whereas a conventional propeller vessel leaves a trail of foam, GHOST's unique design redirects bubbles to surround the twin hulls with pockets of gas. This effect is known as supercavitation, allowing the boat to glide through air rather than water.

GHOST's wings can be repositioned to lift the main cabin above the water. Rising above the bumpy waves ensures a smooth ride, protecting the crew from impact injuries and sea sickness, while also improving the stability and accuracy of onboard sensors and weapon targeting.



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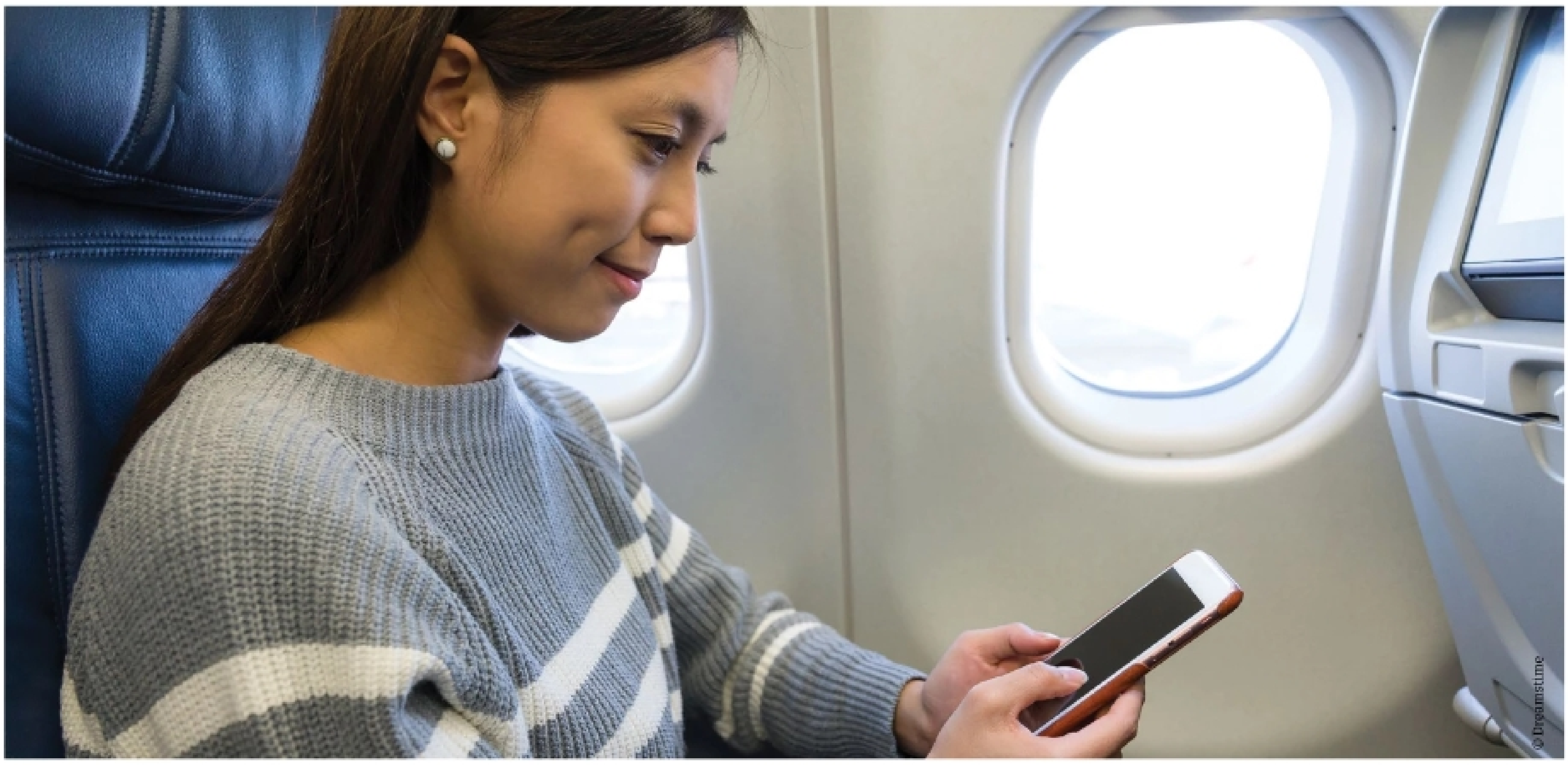

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Why can't you use your phone on airplanes?

Many airlines will now allow travellers to use phones in-flight following a relaxing of regulations.

Previously, there were concerns that radio signals emitted by phones could interfere with aircraft communications, flight control or other onboard electronic equipment. There was never much clear evidence of this, but the introduction of new technologies has minimised the risk of further interference.

Picocell devices act as a mini cell tower on a plane, collecting signals from phones on board and beaming them down to a communications satellite or base stations that reside on the ground.

How do we fill tyres with nitrogen?

While we typically fill our car tyres with regular air, Formula 1 teams and even airlines fill their vehicles' tyres with pure nitrogen. They do this to boost performance and reliability, so should we be doing the same?

The air you pump into your tyres is actually mostly nitrogen anyway – 78 per cent of it to be exact – but it's the other 22 per cent that is the problem. Less than one per cent is water vapour, which at very low temperatures, such as those at high altitudes, and very high temperatures, such as those created when driving very fast, can freeze or expand to make the tyre pressure unstable. For normal driving though, this shouldn't be a problem, so dryer nitrogen won't make much difference.

However, air is also 21 per cent oxygen, and as oxygen molecules are so small, they leak through the tyre rubber over time. Nitrogen molecules on the other hand, are bigger, so they stay inside the rubber for longer and mean you have to get the tyres pumped less often.

© Keisuke Kariya

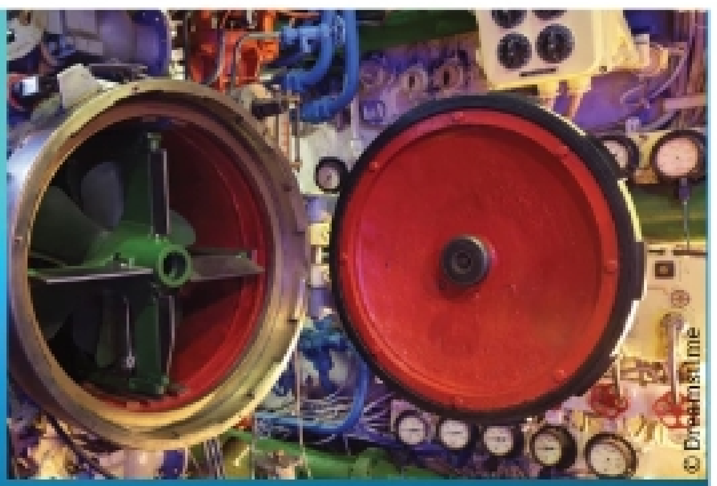
How do we fire torpedoes?

Torpedoes can be launched from both ships and submarines during warfare, using torpedo tubes lined up along the hull.

World War II-era torpedoes were guided towards the target using an internal gyroscope, and their path could be fine-tuned using the rudders after they had been released. A pendulum inside of the torpedo kept it level after its release.

Many modern torpedoes are wire guided, which means that they can be controlled remotely after their launch, before the wire is cut off and the internal guidance system takes over.

Once the torpedo detects an enemy ship, or makes contact with it, the on-board explosive is detonated to rip a hole in its side in order to send it sinking to the bottom of the ocean without a trace.



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Why does airplane food taste so bad?

It's challenging enough to serve up meals in flight, but these can seem even more unappetising due to the effects of low humidity, lower air pressure, and background noise on our sense of taste.

Dry air and low pressure reduce the sensitivity of your taste buds to sweet and salty flavours in foods – although bitter, sour and spicy foods are less affected. Dryness affects our nasal passages, making us a lot less sensitive to smells, which are ultimately very important in our perception of taste. The loud humming you hear while travelling on planes has also been shown to make food seem blander.

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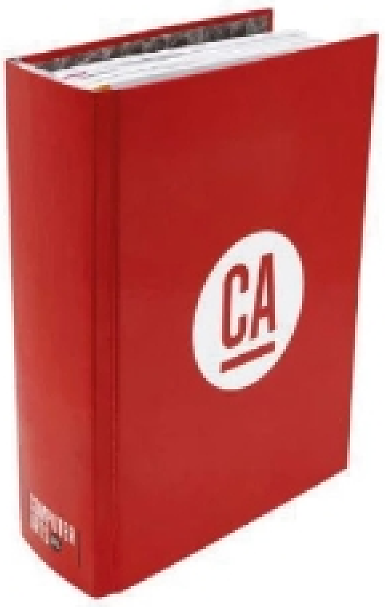

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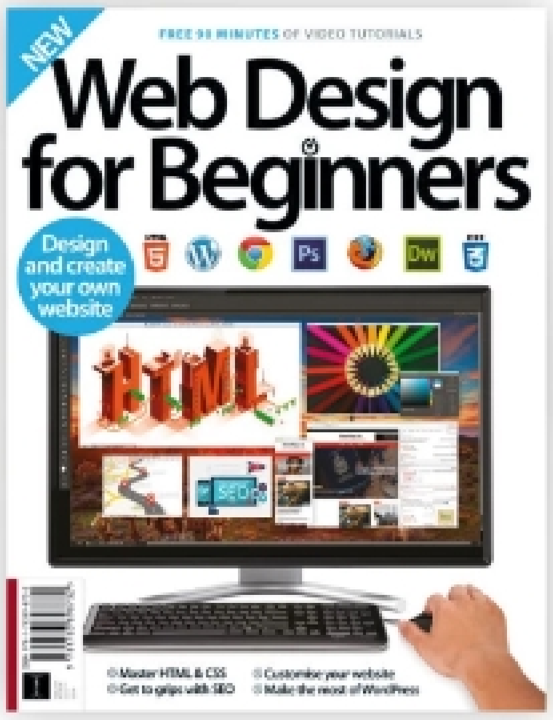
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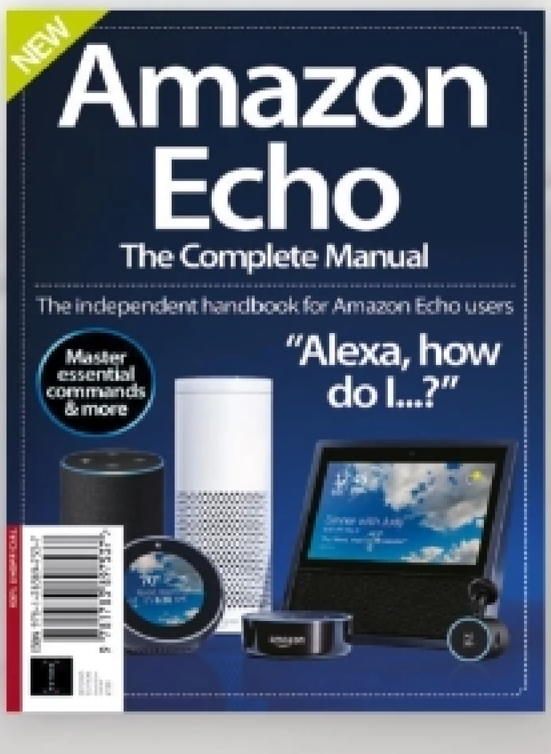
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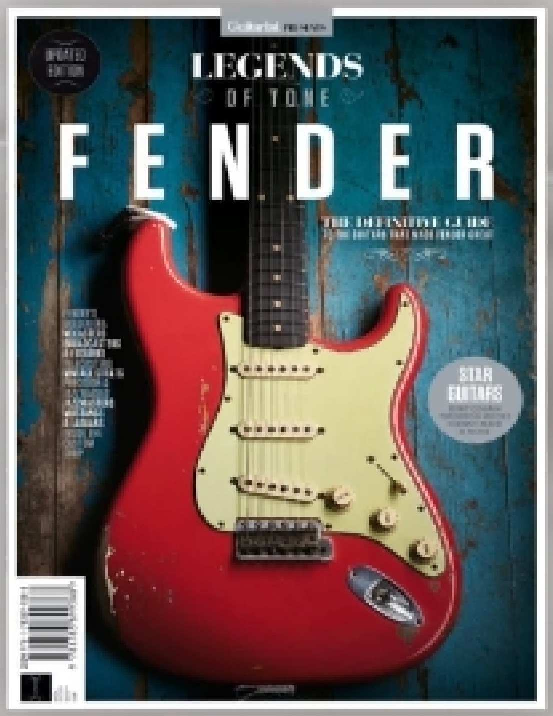

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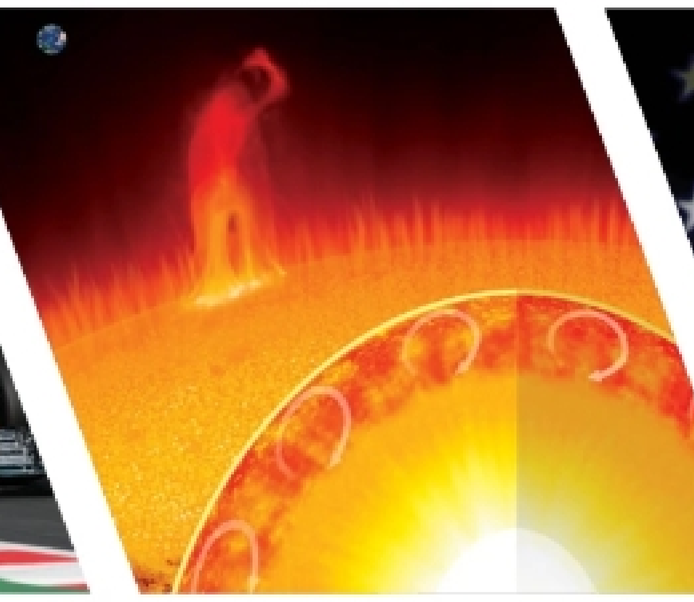
What is a soybean plant?

How is nitrogen put in tyres?



What is the sun made up of?

Who chose America's symbol?

How hard is brain surgery?

What are Earth's land habitats?

Can new tech fight fires?

What are VTOL aircraft?

Satisfy your curiosity with amazing answers to fuel the imagination. Discover incredible facts and information about the world we live in across these six sections:

- *Environment*
- *Technology*
- *Space*
- *Science*
- *History*
- *Transport*

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